SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Special Features

Operators' Training—Ingram

Purification in Lagoons—Parker, et al.

Industrial Wastes Forum

Sodium Nitrate Treatment of Androscoggin River—Lawrance

JUNE, 1950—VOL. 22, No. 6

Make Plans to Attend—

TWENTY-THIRD ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

IN CONJUNCTION WITH

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION (SEWAGE WORKS SECTION)

AND

FEDERAL SEWAGE RESEARCH ASSOCIATION

STATLER HOTEL
WASHINGTON, D. C.

October 9-12, 1950

FEDERATION OF SEWAGE WORKS ASSOCIATIONS
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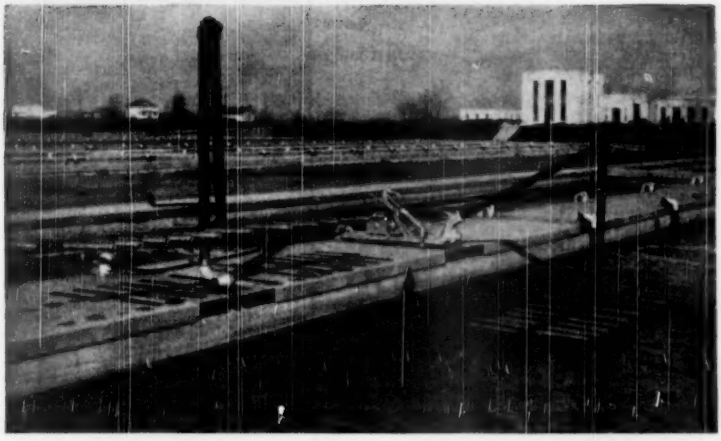
THE OVERWHELMING MAJORITY *specified* "CHICAGO" SWING DIFFUSERS AND PRECISION TUBES



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- **Continuous performance without extra tanks.**
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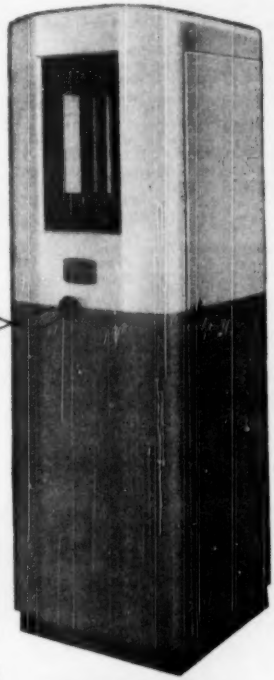

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HOW TO MEASURE TRADE WASTES ACCURATELY

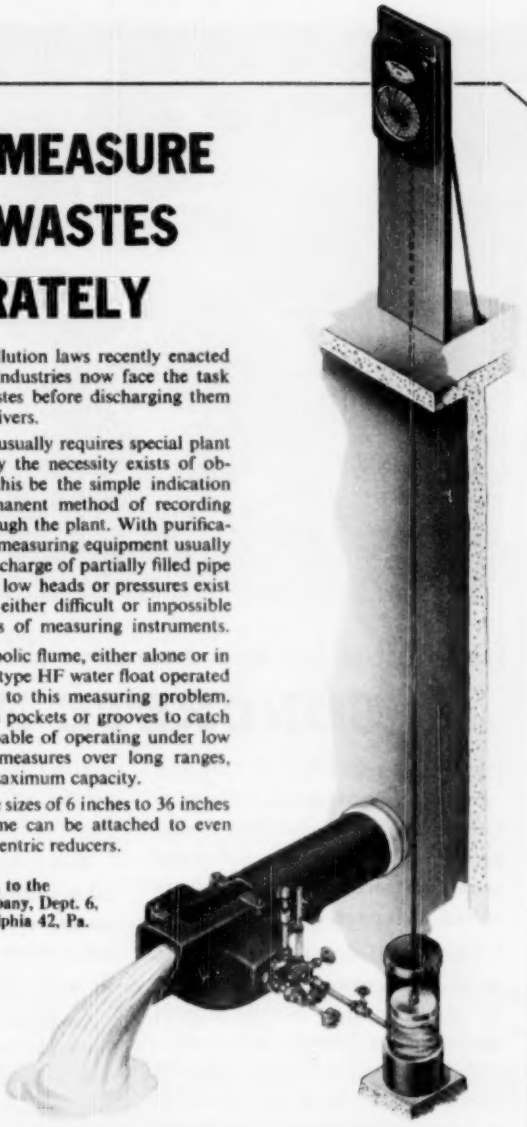
In accordance with anti-pollution laws recently enacted by numerous states, most industries now face the task of purifying their plant wastes before discharging them into adjacent streams and rivers.

This purification process usually requires special plant construction, and invariably the necessity exists of obtaining flow data, whether this be the simple indication of flow rate or a more permanent method of recording and totalizing the flow through the plant. With purification processes of this kind, measuring equipment usually is located at the point of discharge of partially filled pipe or in open channels, where low heads or pressures exist and where measurement is either difficult or impossible when using standard forms of measuring instruments.

The Simplex type S Parabolic flume, either alone or in conjunction with a Simplex type HF water float operated meter, is the ready answer to this measuring problem. Compact in design, with no pockets or grooves to catch sediment or solids, and capable of operating under low flow conditions, the unit measures over long ranges, from maximum to 5% of maximum capacity.

Available in standard pipe sizes of 6 inches to 36 inches diameter inclusive, the flume can be attached to even larger sizes by means of eccentric reducers.

Write for Bulletin 210, to the Simplex Valve & Meter Company, Dept. 6, 6719 Upland Street, Philadelphia 42, Pa.



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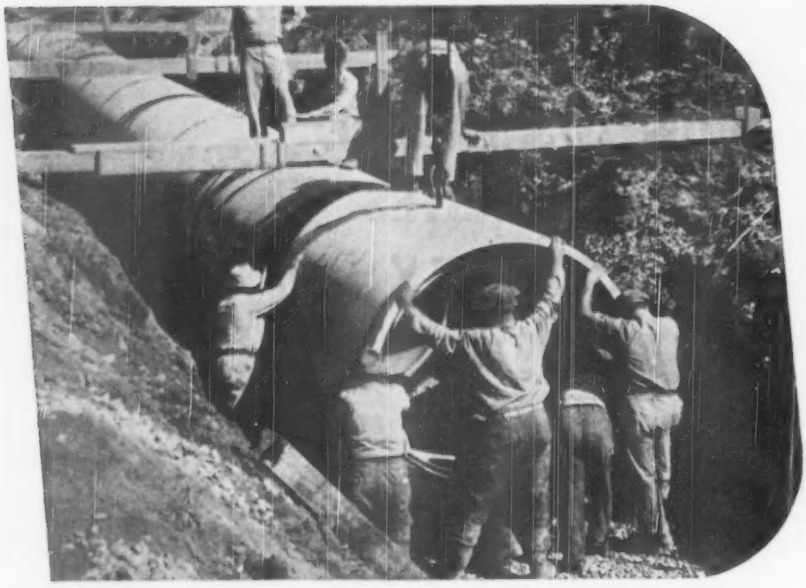

Difficult suburban sewer problem solved with

CONCRETE PIPE

THE Alewife Brook Conduit project in Medford, Arlington, Cambridge and Somerville, northern suburbs of Boston, posed an unusual construction problem that was solved with concrete pipe.

The installation of this difficult, trunk-line sewer required that pipe be placed in open cuts, in tunnels under streets, playgrounds and a railroad, along a brook generally well below the existing water table and finally under the Mystic River.

The project required 8310 ft. of 60-in. and 66-in. (ASTM Specification C76, Table I and Table II) reinforced concrete pipe using two rows of circular reinforcing steel.

This is but another example of the adaptability of concrete pipe. Its structural strength and rugged durability have been proved by many decades of heavy-duty service.

Concrete pipe provides maximum hydraulic capacity. Its tight joints and uniformly dense structure insure minimum infiltration and leakage. It is moderate in first cost, requires little upkeep, lasts longer. Result: ***low-annual-cost*** service.

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Ideal for small communities, isolated institutions, outlying plants

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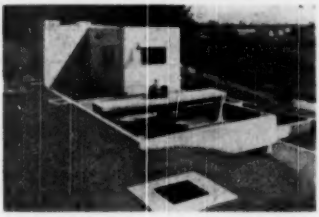

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Many small communities and outlying institutions, compelled to purify wastes but lacking an ample supply of diluting water, have found in the Yeomans "Package" Aerifier an ideal answer to a critical problem.

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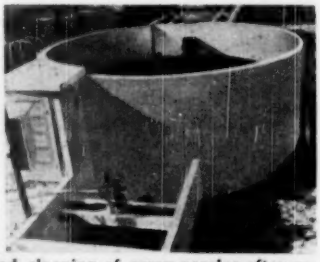

Operating in conjunction with a primary sedimentation tank, the Yeomans "Water-Wheel" Distributor applies settled sewage to a trickling filter—with unfailing dependability. Sewage flows into the rotating trough, and is spread evenly on the filter bed through V-notches and spreader plates. The trough is actuated by a water-wheel and bevel gearing. Filter beds range from 5-foot to 25-foot diameters; and the entire area is effective for treatment. Continuous positive distribution is assured at all rates of flow—which does away with the need for dosing chambers and siphons. There is none of the clogging and cleaning of spray nozzles often required with reaction distributors; and elimination of accessories saves as much as the entire cost of the complete Water-Wheel installation. Maintenance is extremely simple. Numerous Water-Wheel plants—small communities, hospitals, airports, industrial plants—provide impressive proof of this unit's extraordinary efficiency.

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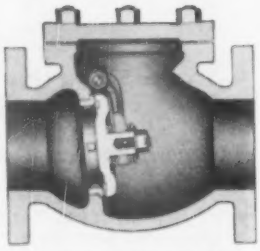
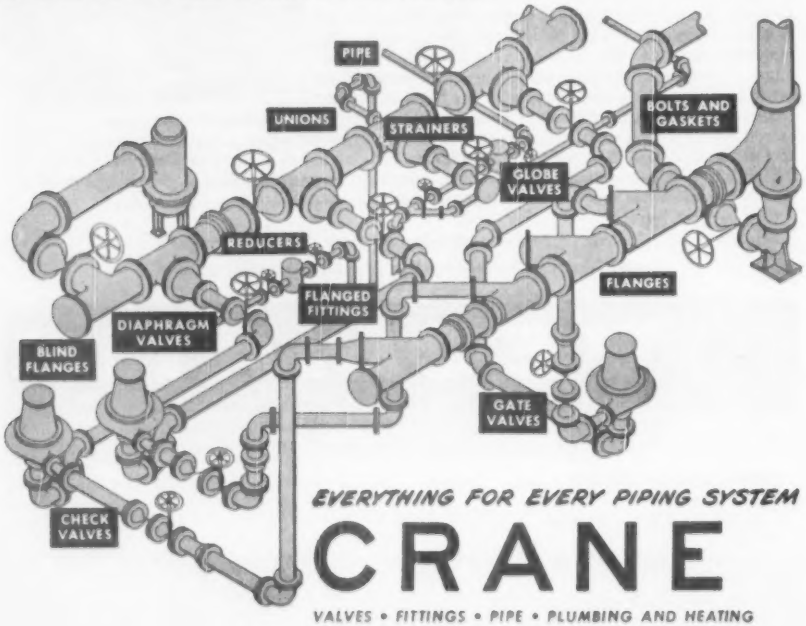


No. 373 brass trimmed check, sizes 2 to 8-in. Also available with leather disc or in all-iron. Sizes 10 to 24-in. have conventional disc-hinge connection. See your Crane Catalog for working pressures.

THIS SEWAGE STATION PUMP ROOM PIPING, FOR EXAMPLE, CAN BE COMPLETELY EQUIPPED BY CRANE



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Capacities range from 3,000 to 50,000 G.P.M., heads from 10 to 50 ft. For complete details, write Dept. AC-6.

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DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

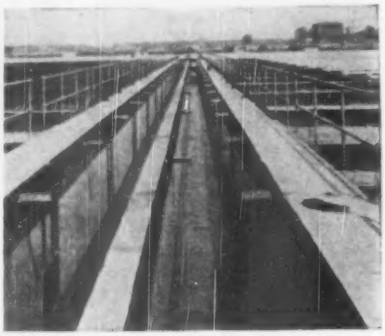
64 EVERDUR* gates

in new Philadelphia sewage treatment plant

Philadelphia chose Everdur† for the 64 slide gates in its new 135-million gallon capacity Northeast Sewage Treatment Plant because of the remarkable record of these copper-silicon alloys for corrosion resistance. The gates were fabricated by the Frederick Grundy Iron Works of Philadelphia for the Virginia Engineering Company, the general contractors.

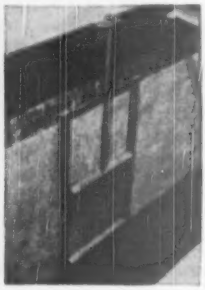
Let us tell you about Everdur—the durable ANACONDA Copper-Silicon Alloys available in practically every standard wrought shape and size, as well as in electrical conduit and casting ingots. Write to The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

Settling basins under construction at new 135-million gallon capacity N. E. Philadelphia Sewage Treatment Plant by Virginia Engineering Co., Newport News, Va.



Influent and effluent channels to settling basins No. 2 and No. 3 showing 32 of the 64 Everdur gates.

Everdur is easy to weld. Here an Everdur angle is being welded to Everdur plate in fabricating one of the 64 gates.



Close-up of one of the gates fabricated entirely of Everdur metal by the Frederick Grundy Iron Works.

Where corrosion resistance counts

ANACONDA copper-silicon alloys*

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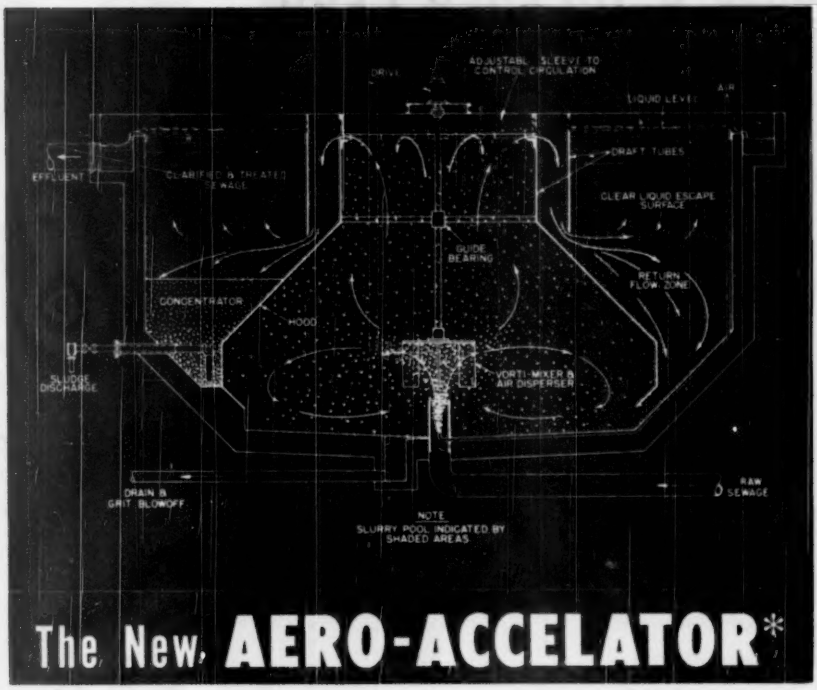

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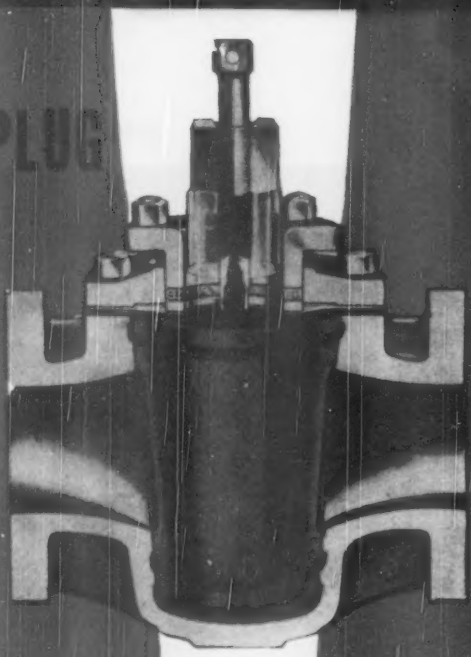
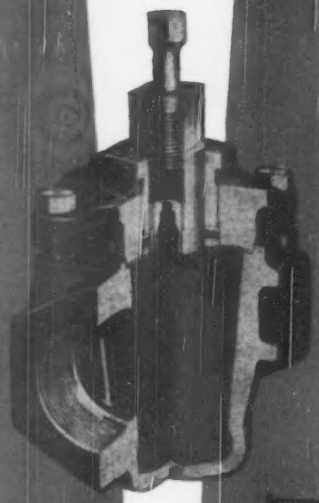


Bolted Gland Type



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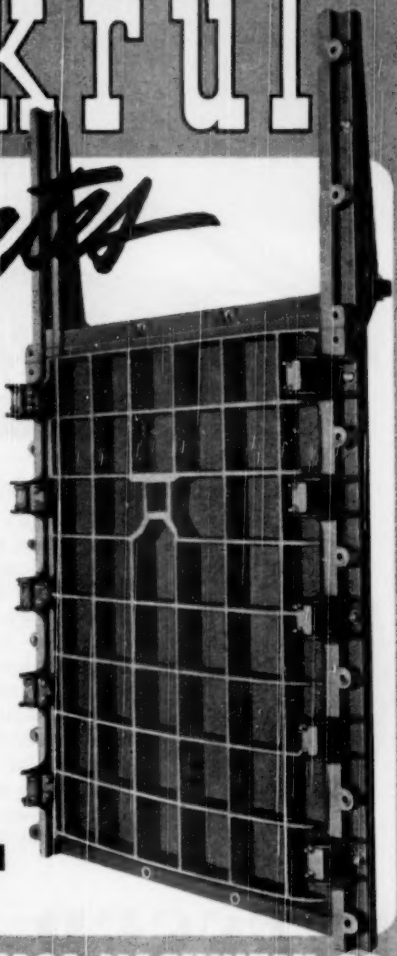

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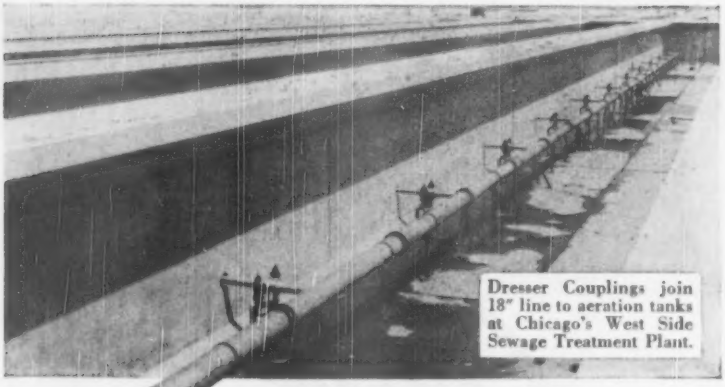

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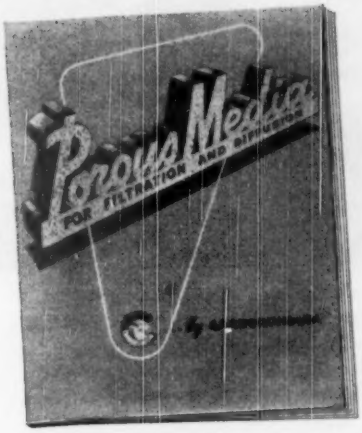

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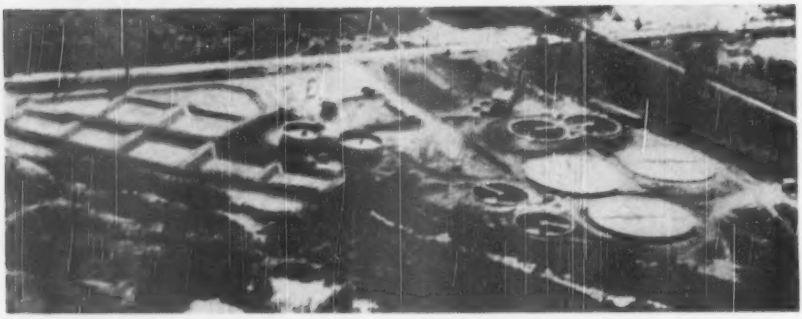
Consulting Engineer Haskins Specifies Inertol Paints throughout two new sewage plants



North Side Sewage Plant, the larger of the two plants at Joplin, Missouri.
Inertol colors and black bituminous paints applied throughout both plants.
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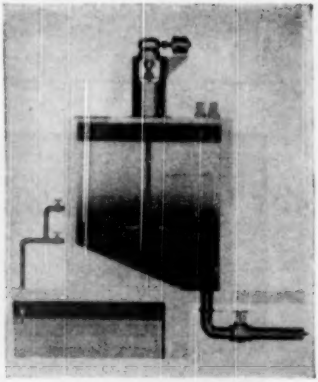
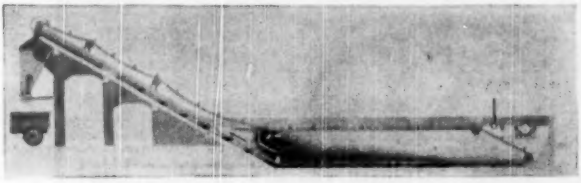
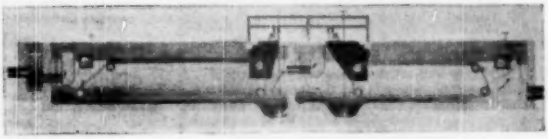


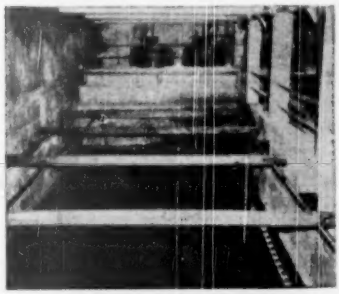
Above: Neutralization is accomplished by mixing lime with acid wastes in the Link-Belt Flash Mixer, which can also be used to treat metal plating wastes or wherever a rapid and thorough mixing of liquids and chemicals is desired.



Above: To prevent stream pollution, and recover valuable carbon, with low moisture content, and practically no hand labor, Link-Belt flight conveyor in a specially designed tank gives excellent results. Can also be used for removal of mill scale from cooling water, etc.



Above: To separate waste oil and heavy solids from refinery waste waters, Link-Belt Straightline oil and sludge collectors in specially designed tanks, give high efficiency, and conform to A.P.I. recommendations.



Above: Many Link-Belt Straightline sludge and grease collectors in catch basins at meat packing houses have paid their costs several times in value of grease and solids recovered. Grease is collected on water surface and solids are pushed along the floor of tank. Solids may be processed for protein animal food and grease recovered by rendering.

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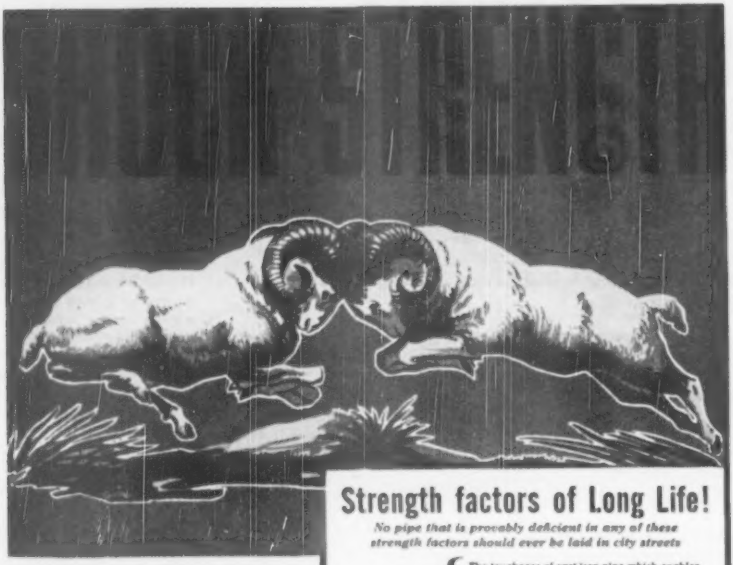

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No pipe that is provably deficient in any of these strength factors should ever be laid in city streets

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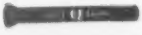

CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

The Journal of the Federation of Sewage Works Associations

Volume 22 **JUNE, 1950** **Number 6**

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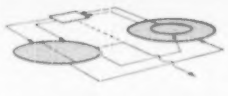

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Sewage Works

SEWAGE WORKS IN THE COLNE VALLEY AREA, HERTFORDSHIRE, ENGLAND *

By W. Fillingham Brown

Chief Engineer, Colne Valley Sewerage Board, Hertfordshire, England

History

During the period between the two World Wars, exceptionally rapid urban development occurred in the Greater London Area, Southwest Hertfordshire being no exception. As a result, many sewerage and sewage disposal systems, especially the latter, soon became seriously overloaded. The difficulties resulting from the overloading of sewage disposal works and the multiplication of cesspools led to joint action by a number of local authorities in Southwest Hertfordshire, the first step being to explore the possibility of unifying the sewage disposal services of the Area on the lines recommended in the Greater London Drainage Report made to the Minister of Health in 1934. A technical report prepared by the late E. A. Sandford Fawcett indicated that a regional scheme of trunk sewers and centralized sewage works was practicable, and could be designed to replace most of the existing sewage disposal works and pumping stations in an area comprising the watershed of the River Colne and its tributaries, the Rivers Chess, Gade, and Ver.

The next step, therefore, was to request the Hertfordshire County Council to promote a bill in Parliament with the object of incorporating a joint board to be made responsible for the administration of the existing sewage disposal services of the area and also for constructing the system of trunk sewers, with a centralized sewage disposal works as recommended in the report.

This decision was made at a conference of the interested authorities held in July, 1935, and immediate promotion was begun of the Hertfordshire County Council (Colne Valley Sewerage, etc.) Bill, which received Royal Assent in July, 1937. The board thus incorporated is known as the Colne Valley Sewerage Board, and has a total membership of 30, the elected representatives of 13 local Authorities. The area served is shown in Figure 1.

The first construction contracts were let in 1938. Other contracts for sections of the trunk sewers and purification works, and for mechanical equipment for the latter, followed, and were continued until the outbreak of World War II. The Board then obtained government approval to continue the construction of a restricted scheme to serve the areas nearest the purification works, but the increasing difficulty of obtaining labor and materials soon made further progress uneconomic and all contracts were therefore wound up and the work left uncompleted.

Work was not resumed until May, 1946. Since that time, progress has been maintained on both sewer and works contracts, reasonably well on the

* Presented at 22nd Annual Meeting, Federation of Sewage Works Assns.; Boston, Mass.; Oct. 17–20, 1949.

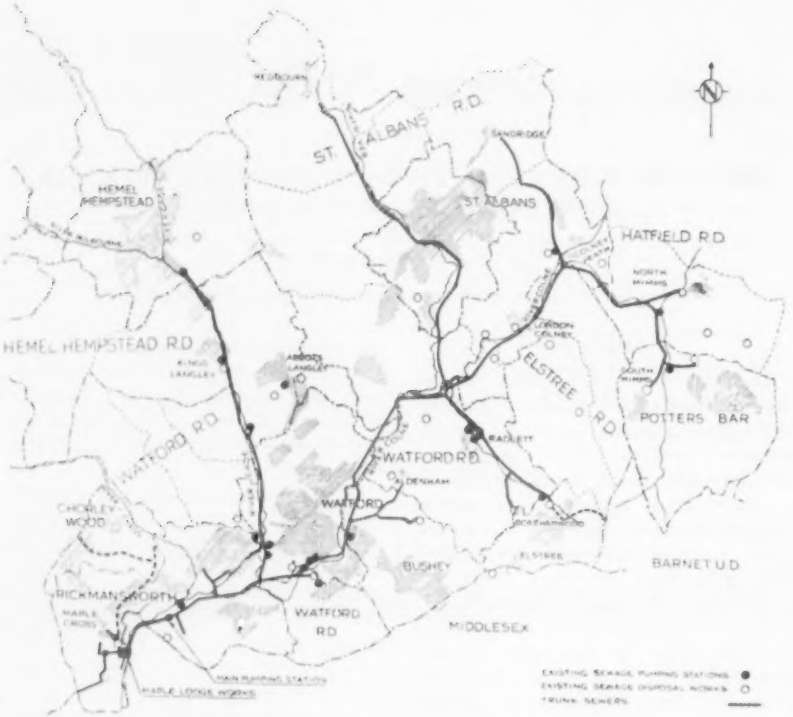

FIGURE 1.—Area served and existing and proposed trunk sewers and sewage treatment plants of Colne Valley Sewerage Board.

former, but less satisfactory on the latter, mainly owing to shortage of skilled labor. The scheme is planned to be put into operation by the end of 1950.

Sewer Design Considerations

Population

The total population of the area to be served by the scheme was estimated in 1936 to be approximately 220,000. It was expected that by 1965 this figure would have increased to about 432,000, and the designs for the trunk sewers were originally based on this latter figure. The present population (1949) is estimated to be approximately 320,000 and it is expected that it will ultimately reach about 500,000 as a result of the planned development of the districts concerned. The Town and Country Planning Act of 1946 provides, among other things, for the establishment of new towns of a limited size outside the Greater London Area, in accordance with the recommendations of "The Greater London Plan, 1944."

In this connection, it may be noted that of the new towns designated under this Act, one, Hemel Hempstead, lies wholly within the Board's area, and another, Hatfield, although only partly within the area, will probably be wholly served by the Board's scheme. In addition, the London County Council is developing a large residential estate near Watford, and has obtained powers to acquire land at Borehamwood for a

similar purpose. These estates, both within the Board's district, are intended to house upwards of 50,000 people at present living in overcrowded or otherwise unsatisfactory conditions in London.

Location

The existing sewage disposal works in the Board's area, totalling about 30 in all, may be divided into two main groups. In the first are the older works, originally irrigation areas and still largely so, situated on high ground where the subsoil is mainly plateau gravel, and to which all or most of the sewage is pumped from a collecting point or points in the river valleys. The second group includes mostly the main newer works, sited in the valleys, and to which most of the sewage flows by gravity only. It will be seen, therefore, that trunk sewers laid principally along the river valleys not only will have all the advantages of a gravity system, but may readily be sited so as to link up and eliminate all the works in the second group directly, and those in the first group indirectly by eliminating the pumping stations.

This was the principle adopted in the design of the Colne Valley Scheme, though in a few cases it was found more convenient to make connection to the existing systems at several points en route instead of at a single point at or near the works. In some places where the river valleys meander it was found preferable to shorten the route of the sewer by taking a more direct course, even though this involved construction in tunnel, but in general the sewers follow the rivers fairly closely.

Under the terms of the 1937 Act, the Board is responsible for accepting sewage, at a rate not exceeding 6 times a dry weather flow (D.W.F.) of 40 g.e.d. (Imp.), from any constituent authority's area "or part thereof," and the trunk sewers were designed with a maximum capacity based on this value. No special allowance was made for trade wastes, but as most of the existing development to be served is drained on the separate system, and all future development is expected to be so drained, it was considered that the basis of design provided a generous margin for all trade discharges likely to be experienced.

Grades and Soil Conditions

Natural gradients in the river valleys were found to be such that, in general, sewers could be laid at the minimum depths necessary to collect the flows at the points of connection to the systems of the constituent authorities, and themselves have gradients giving self-cleansing velocities at all times. It was decided that sewers of circular cross section should be used in all cases, and the diameters required vary from 15 to 75 in. The total length of trunk sewers to be provided will be approximately 55 miles.

The subsoil in the Colne Valley area is mainly gravel overlying chalk. The gravel is alluvial in the valleys and mostly waterlogged to within a few feet of the surface at all times. The chalk is mainly fissured and water bearing. Samples of water taken from test borings along the routes of all the sewers were analyzed, but in no case were sulfates found to be present in quantities likely to be dangerous to concrete. It was decided, therefore, to use spun concrete pipes wherever possible, with concrete surround if necessary. Spun iron and steel pipes have also been used where bad ground was encountered or expected, and in such cases flexible-type joints are used. These remarks refer to sections in open trench, the largest size of pipe used in this situation being 75-in. spun concrete.

Tunnel Construction

As mentioned previously, the routes of some sections of the main trunk

sewer were sited under higher ground. As the diameter was comparatively large, construction in tunnel using segments, as distinct from laying pipes in heading, was chosen as the method to be employed. In the first tunnel sections, constructed before the war and of 75-in. internal diameter, cast-iron segments of the usual pattern were used. After jointing with lead strip, caulked into position, a lining of concrete 2 in. thick over the segment flanges, and reinforced with 4-in. mesh steel fabric, was applied by the "gunite" process, screeded to templates, and trowel finished.

During the war, a reinforced concrete segment similar in most respects to the cast-iron pattern was developed, and with the rapid increase in the cost of cast iron during and after the war it was realized that the use of such segments, if practicable, would result in a very large saving in the cost of the tunnel sewers. The concrete segments were used successfully in the construction of tunnel shelters in the London clay, but there was no experience with their behavior in other types of ground; in particular, it was not known whether their use in water bearing strata would result in a watertight structure. This was a point of more than usual importance in the present instance, and for two very different reasons. First, the subsoil was known to be water bearing, and in some localities under a considerable head at the depth of the sewer. It was necessary, therefore, to exercise the greatest care, both in design and construction, to prevent infiltration, so often the cause of unnecessarily high pumping costs. Secondly, the whole of the water supply of the area, and of densely populated areas in the adjoining county of Middlesex, is obtained from wells in the chalk, many of which are comparatively close to the route of the sewers. The local water suppliers had, therefore, obtained the inclusion in the Board's Act of protective clauses designed to insure a watertight sewer. Admittedly, if the sewers are not watertight, infiltration of subsoil water is a more probable result than the escape of sewage, as in most localities the subsoil water is under considerable pressure at the depth of the sewer and the sewage is not. However, the subsoil water level is known to vary through a wide range in certain places, and it would not be safe to assume that sewage would never escape into the subsoil at these points.

Experimental Length

With these considerations in mind, it was decided that although the saving in first cost by the substitution of concrete for cast-iron segments was likely to be substantial, actual experience with construction in water-bearing ground was essential before their value could be assessed in the present instance. A 275-yd. length of 75-in. diameter sewer was chosen, therefore, as an experimental length to ascertain whether reinforced concrete segments would be suitable in ground typical of conditions to be expected in the rest of the Colne Valley area. If the experiment succeeded, the length would become part of the main sewer, and the remainder of the tunnel sections would be constructed similarly. If it failed, the length would have to be either reconstructed in cast iron, or abandoned and a parallel length constructed alongside.

From the test borings it was known that the length chosen was entirely in chalk, and it was expected that the maximum head of water above the sewer center line would amount to about 25 ft.

All joints, both longitudinal and circumferential, were made with cement mortar mixed with a quick-setting and waterproofing compound, and a 3-in. thick reinforced concrete lining was applied. The final ½ in. in the invert was subsequently applied

by the "gunite" process under a later contract.

As far as may be judged at present, the experiment was an unqualified success. The length is quite watertight under the normal head of subsoil water (see Figure 2) and it was decided, therefore, to employ pre-cast concrete segments with a concrete lining for all tunnel sections still to be constructed.

Flow Measurements

Standing-wave flumes and recorders are to be installed at suitable points on the sewerage system in order to ascertain, directly or by difference, the quantities of sewage received from the various districts served by the scheme, and the rates of flow. The flumes are to be of concrete, cast in place, with inverts of semi-circular section. The recorders will be fixed above ground in teak cases enclosed in special cast-iron outer cases bolted to a concrete foundation block.

Design of Pumping Stations

As previously mentioned, the sewers are laid mainly in the river valleys, and the gradients of the sewers approximate the river gradients. The levels at which the sewers are to be laid are, however, mainly below the river levels, and for this reason it would be impossible to construct storm overflows to the rivers. As the Board is not obliged to accept flows exceeding 6 D.W.F., this fact is not likely to cause difficulties. It does mean, however, that it becomes necessary to pump the entire flow.

In order to explain further decisions in this connection, it will be nec-

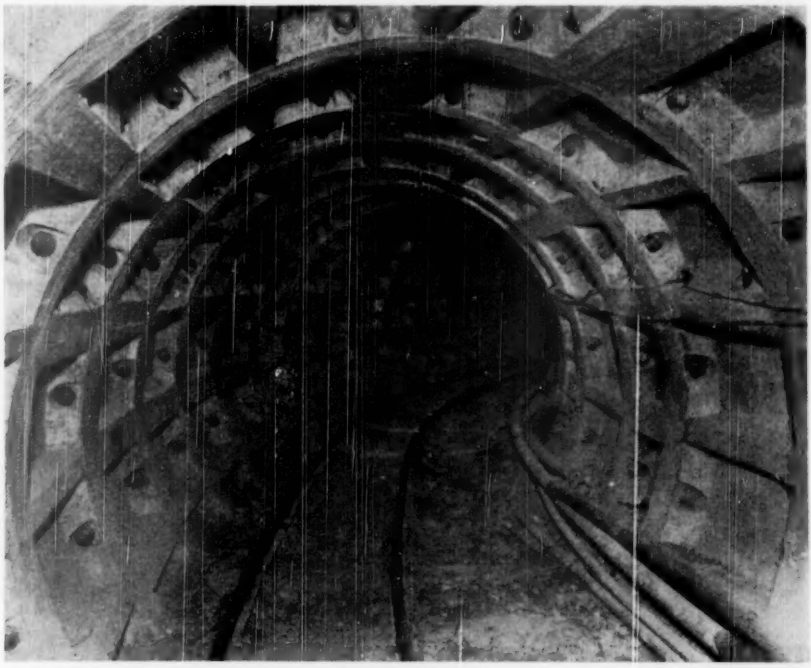

FIGURE 2.—Experimental tunnel section of main trunk sewer, showing pre-cast concrete segment construction.

essary to describe the site of the treatment plant. This comprises some 30 acres of land at Maple Lodge, about 2 mi. south of Rickmansworth, lying near the River Colne and Grand Union Canal, which it adjoins (see Figure 3). Like much of the low-lying land in the valleys of the Colne and its tributaries, it was liable to flooding, and the subsoil is water-logged to within 2 or 3 ft. of the surface. The subsoil is alluvial gravel, with some surface peat, overlying chalk, the latter being about 20 ft. below the surface. Construction of large tanks in such ground would involve exceptional difficulties and very heavy expense, not only in dewatering the excavations, but also in providing adequate strength and stability against the head of water present. For these reasons, it was decided to construct the works above ground as far as possible, and the top water level in the sedimentation tanks is approximately 10 ft. above original ground level. A sufficient depth of excavation was chosen to provide a stable foundation in all cases, and also enough excavated material to supply filling and embankments between and around the tanks, etc. This decision made it necessary to pump all the sewage before purification.

Downstream from Rickmansworth the valley of the Colne now consists largely of a chain of lakes formed as a result of gravel winning operations. Consequently it would be almost impossible to lay a large sewer along the valley to the Maple Lodge site. Diffi-

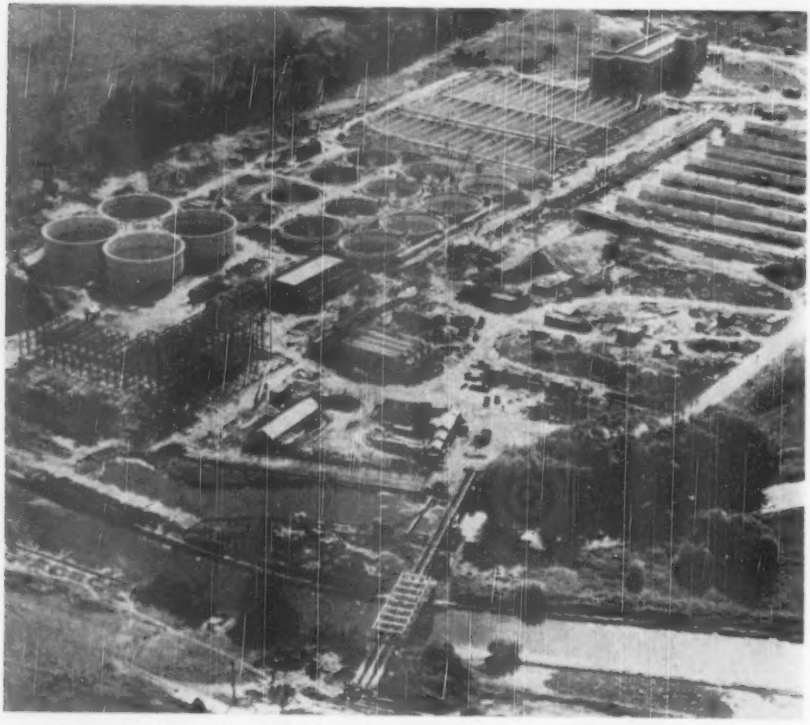

FIGURE 3.—Aerial view of Maple Lodge sewage treatment plant under construction.

cult canal and river crossings would also be involved; therefore, it was decided that it would be more economical to construct the main pumping station on a site near Rickmansworth and about 1½ mi. from the Maple Lodge works, and deliver the sewage to the works through force mains laid in the higher and drier ground along the east bank of the canal. The canal and river crossings will be by steel girder bridge. Two pumping mains, each of 48-in. diameter, will be laid now, and a third main of the same diameter at a later date. The mains are of steel, lined and sheathed with bitumen, and hessian wrapped. They are jointed by welding, the bitumen lining and sheathing being made good after the joints are made.

The pumping station is of normal design with reinforced concrete substructure comprising wet and dry wells, and brick superstructure. The static head is between 20 and 25 ft.

Equipment

The equipment of the stations comprises vertical centrifugal pumps mounted in the dry well, direct coupled through steel shafting to electric motors at ground level. Completely automatic control will be provided and indicators will be installed showing, by means of a mimic diagram on a panel in the power house at the works, the pumps that are in operation and the level of the sewage in the wet well. At the main station, 6 D.W.F. pumps of approximately 4,000-g.p.m. (Imp.) capacity, and 3 storm-water pumps of approximately 10,000-g.p.m. (Imp.) capacity will be installed in the first instance, and additions made as required in the future up to a total of 9 D.W.F. and 4 S.W.F. pumps. All these pumps will be driven by variable speed motors.

Power for operating all the pumping stations will be generated at the works and transmitted by high-tension cables laid underground. Connections for the level indicating mechanism, telephones, etc., are provided by separate multi-core cables.

Design of Treatment Plant

General

The whole of the effluent from the works will be discharged into the River Colne, a comparatively small river which joins the Thames above the intakes of the Metropolitan Water Board. It will be evident, therefore, that the highest standards of purity, consistent with economy, will be required of the effluent. The Board has undertaken, as a result of representations made by the Thames Conservancy and Metropolitan Water Boards, not to discharge any effluent not complying with the Royal Commission Standard for B.O.D. and suspended solids (20 and 30 p.p.m., respectively). In addition, all effluent must pass a test for putrescibility. The significant point in this connection lies not so much in the standards themselves, as in the fact that they are to apply at all times to the whole discharge from the works. This is a departure from the recognized Ministry of Health design standards, which only require the provision of full treatment for all flows up to 3 D.W.F., partial treatment for flows between 3 and 6 D.W.F., and no treatment for flows exceeding 6 D.W.F. As mentioned above, the relative levels of trunk sewers and rivers make the provision of storm overflows impossible, and as the Board is not obliged to receive flows exceeding 6 D.W.F., the question of the standard of purity of discharges of untreated storm water does not arise. The acceptance by the Board of a "full treatment" standard for flows between 3 and 6 D.W.F. does constitute, however, an important advance in sewage purification standards and consequently in the prevention of river pollution.

The adoption of such a standard in small- and medium-sized schemes

would result in very substantial increases in the capital cost of the purification works; the additional plant provided, whether storage tanks and pumps, or extra biological purification equipment, would be uneconomic in that it would be out of use for much of the time. On the other hand, it is possible in a large regional scheme to achieve this high standard at comparatively low cost, and with economy, provided certain methods of purification are adopted. In such a system peak flows do not, except in very exceptional circumstances, arrive at the purification plant at the same time. The resultant peak for wet weather flows is thus substantially below the aggregate of the peak flows contributed by the individual towns or districts served. One effect of this balancing is to cause a larger proportion of what would be the flow above 3 D.W.F. at the points of entry into the trunk sewers, to pass the storm overflow weir at the works and receive full treatment. This in turn reduces the actual volume of storm water flowing over the 3 D.W.F. weir, and consequently the capacity of the storm-water tanks necessary to provide settlement need not be so great. Alternatively, if normal storm tank capacity is provided, overflows from them are correspondingly smaller and less frequent, so that a larger volume may be pumped back for full treatment.

Furthermore, if power is derived from sludge gas, almost a foregone conclusion in a regional scheme, generous aeration can be provided cheaply, and an effluent consistently well above Royal Commission standard thereby assured. The effect of mixing such an effluent with the occasional overflows of settled "storm water" has been found at the West Middlesex works to produce a resulting effluent still within Royal Commission limits.

These considerations were taken into account in designing the Board's works at Maple Lodge, and it was decided to adopt the diffused air, activated sludge system of purification, with a capacity sufficient to give 12-hr. aeration on dry weather flow, and an air supply of 1.5 cu. ft. per gal. (Imp.) of D.W.F. treated. Sedimentation and storm-water tanks of a capacity equivalent to 7½ hr. and 6 hr. D.W.F., respectively, were chosen for preliminary treatment, and it was also decided to employ sludge digestion to provide methane gas for the generation of the power required for pumping, air compressing, and other purposes. A flow diagram for the plant is shown in Figure 4.

Preliminary Treatment

Four grit removal channels, fed from a common header channel into which all the force mains discharge, will be provided. Each channel has an effective length of 60 ft. and approximates in cross-section the parabolic shape necessary for maintaining uniform velocity of flow at all levels when controlled by a standing-wave flume. The flumes are 12 in. wide at the throat, and the system will maintain a forward velocity of 1 ft. per sec. at all levels. Inlet and outlet penstocks are motor operated, and automatically controlled from the flow level upstream of the 3 D.W.F. gauging and control flume. The channels may be isolated for grit removal and can be arranged to come into operation successively in any pre-determined order. The outlet penstocks will not open simultaneously with the inlets, but some seconds later, in order to allow the channel to fill to the operating level when being brought into operation, or to empty when being taken out of operation. Each channel has a capacity of 2,400 c.f.m., being approximately 2 D.W.F. on present flow. Three channels will deal, therefore, with 6 D.W.F. (present), leaving one as a standby. For reasons given above it is expected that the four channels

will provide enough capacity for all future requirements.

Each channel is provided with two subsidiary channels for the storage of grit. When a channel requires emptying, it will be taken out of operation by closing first the inlet and then the outlet penstocks. The small quantity of sewage still remaining in the channel, together with the grit, will then be conveyed to a grit washer through a centrifugal-type grit pump housed below the channel structure. High-pressure water is provided for sluicing the grit to the outlet pipes and for washing the channels. The grit washer is of the vertical upward-flow type, the wash water being obtained

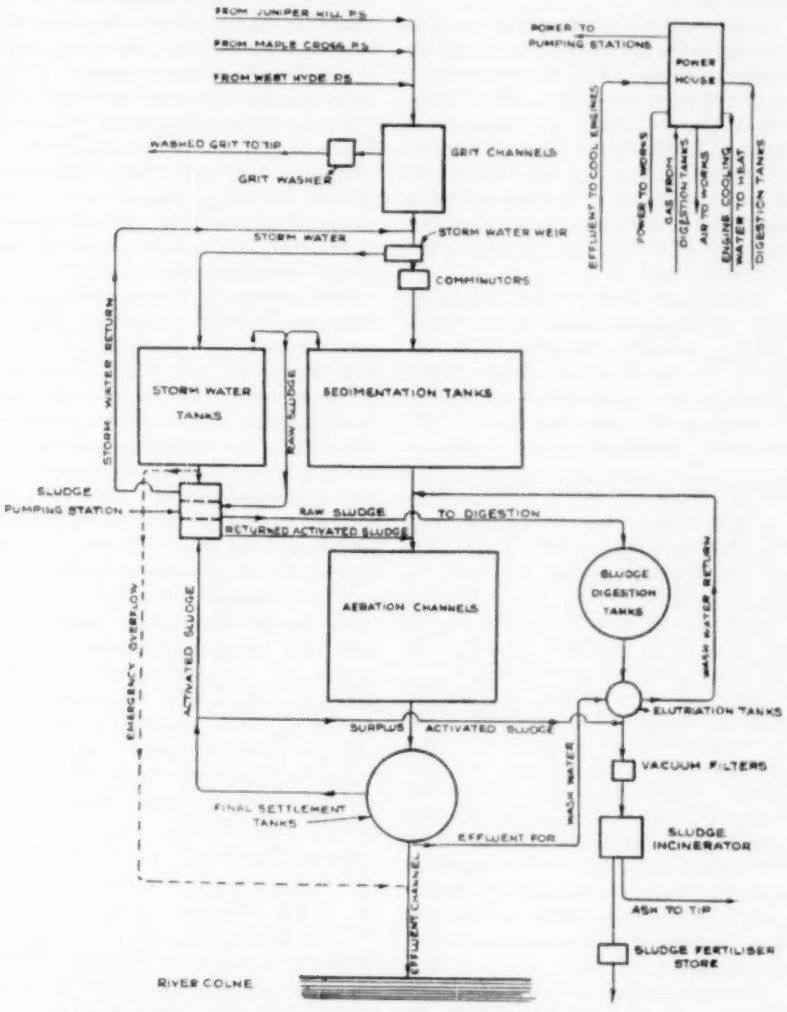

FIGURE 4.—Flow diagram of Maple Lodge sewage treatment plant.

from the River Colne and pumped to the lower part of the washer through a number of jets. The mixture of wash water and sewage will flow over a peripheral weir at the top of the washer and be returned to the main sewage flow for treatment, while the clean grit will settle to the bottom of the hopper. It will be removed by means of the grit pump to a nearby gravel pit.

Immediately downstream of the grit channel is the storm-water weir, where flows exceeding 3 D.W.F. are diverted to the storm-water tanks. This quantity of flow is controlled, within more accurate limits than a long weir parallel with the direction of flow would provide, by means of a motor-operated penstock controlled by the level of the flow immediately upstream from the 3 D.W.F. flume.

Instead of screens for removing large solids three 36-in. comminutors will be installed immediately downstream of the 3 D.W.F. flume. Any two of these machines will be capable of passing the maximum flow to be given full treatment in the works.

Sedimentation and Storm-Water Tanks

Single-stage sedimentation in rectangular tanks was chosen for effecting removal of solid matter, the total retention period allowed being 7½ hr. D.W.F. In the designer's view no advantage was to be gained by adopting two stages for sedimentation, and for economy of construction and sludge scraping equipment rectangular tanks were preferable to circular, and had no apparent disadvantages in efficiency. Sludge removal will be by Mieder-type traveling bridge scrapers operating at frequent intervals while the tanks are in use. The sludge is discharged from the hoppers by hydrostatic head through visible outlets and flows by gravity to the sludge pumping station.

The storm-water tanks are of identical size, shape, and design (272 ft. by 52 ft. by 10 ft. mean water depth), and with the sedimentation tanks form a single battery of tanks ranged side by side. There are several advantages in this arrangement. Apart from economy of space, all the tanks may be scraped by a common scraper or pair of scrapers, and the storm-water tanks may be converted to sedimentation tanks merely by altering the inlet penstocks. In this way, future extensions may be saved if the tank capacity provided is proved in practice to be unnecessarily large by reason of the balancing effect of the trunk sewerage system, or because all new development will be on a strictly separate system of drainage. Space is left for the construction of additional tanks of either kind if required, but four sedimentation and three storm tanks of the dimensions given above are considered enough for present requirements.

The tanks are fed from pressure culverts constructed under the Mieder transfer carriage platform, and running transversely along the south end of the battery. Such an arrangement is economical and easy to construct, but will not give equal distribution to the tanks. In order to improve this, the cross-section of the culverts changes several times throughout their length, and the inlet penstocks will be adjusted to provide the rest of the balancing necessary. The inlets to the tanks consist of vertical shafts, four per tank, discharging near top water level. An inclined concrete baffle, partially submerged, is provided to deflect the flow downward and discourage short circuiting across the surface of the tank. Weir outlets are arranged under the scum channel platform. The common outlet channel, running transversely across the north end of the battery, conveys tank effluent to the aeration channels through culverts situated between the sedimentation tanks and the storm-water tanks. In all tanks, decanting pipes are provided leading to a main pipeline connected to the sludge pumping station,

where the contents of tanks may be pumped back for full treatment.

Biological Purification Plant

From the first, it was intended to generate power from the gas evolved during the sludge digestion process, so that there was no need to sacrifice other advantages in favor of economy in power. It was decided, therefore, to use the diffused air, activated sludge system, and to provide for generous air supply and ample pumping capacity for the return of activated sludge.

The aeration units each consist of a flow and return channel 15 ft. wide by 13 ft. effective depth, and a total length of 616 ft. Eight such units are being provided now, and space is left for others to be added. The 8 units, one of which can be used for re-activation if necessary, will provide 12-hr. aeration for a flow of approximately 12 m.g.d. (Imp.). The "ridge and furrow" arrangement of diffusers is adopted throughout, experience at the West Middlesex works having indicated that it is slightly more efficient than the "spiral flow" arrangement. In 5 of the units, the diffusers are of the older flat pattern, these, with the necessary trays and air feed pipes, having been delivered and put into storage before construction was suspended. In the remaining three units, the newer dome type diffuser will be installed, and it is expected that future units will be so equipped.

Provision was made in the original design for a net air supply of 1.5 cu. ft. per gal. (Imp.) of sewage treated. Three turbo-compressors, each with an output of 6,500 c.f.m. free air will be installed in the first instance, and a fourth machine at a later date when required. It is expected that the air pressure will be approximately 7½ lb. per sq. in. at first, and the compressors are designed to give their full output against that pressure. A spare set of gears is provided for all machines to enable them to deliver the same maximum quantity (6,500 c.f.m.) at a pressure of 9 lb. per sq. in., or alternatively, an increased output against lower pressures. In addition, a large range of output may be obtained below the maximum by means of the variable speed hydraulic coupling with which each machine is equipped.

The inlet and outlet channels extend transversely across the eastern end of the battery, the inlet channel being adjacent to the ends of the aeration channels and connected to each of them by a 4-ft. by 3-ft. hand-operated penstock. Returned activated sludge will enter the inlet channel at its northern end through a vertical pipe fixed in the floor of the channel. Here it meets the flow of settled sewage, and as the directions of flow of the two streams are at right angles, rapid mixing is expected to result. Returned activated sludge can be pumped directly to the point indicated or may first be reaerated in the adjoining unit before entering the inlet channel at the same point. The outlet channel is connected to each aeration unit through a valve-controlled Venturi meter. Both inlet and outlet channels, and also the feed channels to the final settlement tanks, are provided with a row of aeration tiles, and air will be used to prevent the sludge from settling and to keep it fresh. The space between the inlet and outlet channels is used to house the Venturi meters and float chambers, and to provide a control gallery.

The activated sludge is returned by two screw volute-type pumps, each of 4,500 g.p.m. (Imp.) capacity. On the ultimate D.W.F. originally taken as a basis of design, this represented a proportion of 75 per cent, but on the ultimate flow now expected it will be approximately 65 per cent. In addition, two storm-water return pumps of a similar type, but delivering 6,000 g.p.m. (Imp.), may be used to return activated sludge if required, so that a total capacity of 1.5 D.W.F. will be

available for this purpose, except when storm water is being returned.

Final Settlement Tanks

The final settlement tanks are circular, 60 ft. in diameter, 8 ft. side water depth, and with hopper bottoms at a 30° slope to the horizontal. At present, 12 tanks are being constructed, and space is provided for another four. It is expected that the 16 tanks will be adequate to serve the requirements of the ultimate population. They are designed with central inlets and peripheral weir outlets, and will be equipped with ring-type scrapers having four suspended booms, to which trailing scrapers are attached. The upward velocity at maximum flow will not exceed 7 ft. per hr. Sludge will be removed continuously under hydrostatic head through adjustable, visible-discharge bell-mouths, and will flow by gravity to the sumps of the sludge pumping station. Two of the tanks are arranged for operation as sludge thickening tanks if required.

Sludge Pumping Station

Most of the pumping required in the works is concentrated in a single building. The equipment comprises 4 vertical, double-ram, reciprocating pumps, each of 108-g.p.m. (Imp.) capacity, specially designed for pumping sewage sludge, and 4 screw volute-type pumps, 2 of 4,500-g.p.m. (Imp.) and 2 of 6,000-g.p.m. (Imp.) capacity. All pumps are driven by variable speed electric motors, the screw volute pumps being direct-coupled and the reciprocating pumps having multiple V-belt drives.

Sludge Digestion Tanks

Four flat-bottomed tanks, each 76 ft. in diameter and 32 ft. deep, are provided for the digestion of the primary sludge only. All the tanks will be equipped with floating gas holders of steel construction, and with stirring mechanisms. Three of the tanks will be heated by means of water from the water jackets of the power units, supplemented by waste-heat boilers if required. The hot water circulates in coils of 3-in. diameter steel pipes fixed on the walls of the tanks. The fourth tank will be unheated and will be used for secondary digestion and storage of sludge or separated water, or for storage of gas, the gas holder having an extra long skirt for this purpose. The tanks are arranged in a square and the space so enclosed is roofed in to form a control chamber, all pipework and valves necessary for operation being located there.

Pipes and valves are provided for removing scum, for sampling the contents of the tanks at various levels, and for recirculating sludge or transferring sludge or separated water from one tank to another. The combined capacity of the three heated tanks is 440,000 cu. ft. or approximately 0.9 cu. ft. per capita of the ultimate population now expected. The total gas storage available under normal operating conditions will be 120,000 cu. ft., representing approximately 6½-hr. supply when 3 power units are running.

Explosion risks will be minimized by the installation of a special gas detection apparatus, making use of the catalytic reaction of a heated metallic filament in the presence of methane. The change of temperature resulting from this reaction affects the conductivity of the filament, and the variation in conductivity depends on the proportion of methane present in the atmosphere surrounding the filament. Thus, by using a Wheatstone bridge circuit, a galvanometer may be calibrated to indicate the percentage of gas present in the atmosphere. At the Maple Lodge works one detector element will be installed in the control chamber of the digestion tanks, one in the gas governor chamber in the basement of the powerhouse, and three in the pipe gallery. All detectors will be connected to a panel in the powerhouse, and will activate a multiple-pen recorder, spot reading meters, and visual or audible alarms operating not

only when a pre-arranged concentration of gas is reached, but also when a failure of the detector element, or of the current used for heating it, occurs.

Power and Compressor House

All pumping, air compressing, and other mechanical plants will be electrically operated and all electric power required for these purposes and for lighting, etc., will be generated at the plant in a single building. The power units, ultimately 6 in number, comprise 6-cylinder vertical diesel engines direct-coupled to 750-kv.-a. alternators. The engines are of the "dual-fuel" type; that is, they are capable of operating on oil, or on sludge gas, or on a mixture of the two fuels in any proportion. When supercharged they will develop 950 hp., but with atmospheric induction the rating is approximately 660 hp. The working speed is 300 r.p.m.

The alternators will generate current at 3,300 v., 50 c. As a large proportion of the power load will be used for pumping sewage at a station about 1½ mi. distant from the plant site, it was found more economical to generate at this voltage and transform down to 440 v. wherever required.

The power requirements at the plant and pumping stations may be summarized as follows:

Units	Power Required (hp.)
Sewage pumping	130
Sludge pumping	70
Aeration	960
Sludge disposal	320
Tank scraping and stirring mechanisms, comminutors, etc., and lighting	20
Total	1,500 hp.

These figures refer to the requirements of normal dry weather flows from an assumed ultimate population of 500,000.

In addition to the power plant, the building houses the turbo-compressors mentioned above, and all the necessary auxiliary equipment, including transformers, switchboards, waste-heat boilers, heat exchangers, circulating pumps, fuel and lubricating oil purifying plant, control and instrument panels, etc.

Sludge Disposal Plant

It is generally admitted that the methods of sludge disposal in use in England have not advanced appreciably for many years, and are far behind the processes of biological purification not only as regards convenience and avoidance of aerial nuisance, but also in scientific control. The reasons are fairly obvious. Separation of sewage solids from the conveying water involves a series of processes, each progressively more difficult and, therefore, more costly to carry out. Because the final product of this separation was, until quite recently, of negligible value, it is not surprising that in the past designers have had to restrict the treatment of sewage sludge to the earlier and easier processes of the series. Sedimentation, the first, easiest, and cheapest, has been used ever since the natural biological processes of oxidation carried out in the soil were intensified and brought under control. The resulting sludge may also be disposed of by application to land in several ways and up to the present few sewage disposal authorities have found it necessary to undertake any of the further stages of the separation process, all of which require the application of heat in some form to drive off more water.

When the preliminary designs for the Maple Lodge works were under consideration, two problems in connection with sludge disposal were encountered. One was the successful disposal of surplus activated sludge, experience having shown that this sludge is not very susceptible to anaerobic fermentation and is extremely difficult to dry on beds. The second problem was the prohibition, imposed by the clauses inserted in the Board's

Act for the protection of local water interests, against the drying of sludge except on watertight beds. It was feared that the sludge liquor, if allowed to soak into the gravel subsoil, might pollute the nearby wells in the underlying chalk.

It was realized that the cost of providing watertight beds would be very high and that it might be found more economical to adopt one of the methods of mechanical dewatering and/or heat drying. If such a process could also deal successfully with surplus activated sludge and provide a greater measure of scientific control to the process of sludge disposal as a whole, it would have great advantages. After a thorough investigation of all the available processes, especially those in use in the United States and Canada, it was decided to employ digestion of primary sludge only, in order to produce sludge gas for generating power, followed by vacuum filtration, flash drying, and incineration of both digested and surplus activated sludge.

After digestion, the primary sludge will be elutriated in two circular tanks equipped with revolving sludge scraping and thickening mechanism. Final effluent will be used as the elutriate and will be returned, along with digester supernatant, to the aeration plant for treatment. The tanks will be arranged to operate in series or in parallel, the volume of elutriate being three times the volume of sludge in the latter case, and six times in the former.

The vacuum filtration installation will comprise six Oliver filters, each 8 ft. in diameter by 12 ft. long, arranged in line on the first floor of the filter building. The subsidiary equipment, such as air compressors, sludge and filtrate pumps, and vacuum pumps, will be housed on the ground floor below.

Provision is being made for the production of chlorinated copperas for use as a sludge conditioner, ferric chloride being virtually unobtainable in the quantities required. The possibility of using spent hydrochloric acid, used in iron pickling processes, as the basis for a sludge conditioner is being investigated.

Sludge drying and incineration will be on the Raymond system, well-known in the United States and Canada, but hitherto not used in England. Four units, each capable of evaporating 3,572 lb. of water per hour, will be installed in a building adjoining the filtration building. Filter cake will be conveyed to the plant by means of belt conveyors capable of handling digested sludge and activated sludge separately.

The reasons for recommending flash drying and incineration for the disposal of sludge were mentioned above, but at the time this decision was made (before the war) it was not anticipated that the demand for sludge for use as a fertilizer would be sufficient to justify drying it. Since that time, however, a shortage of fertilizers has arisen, and the need to return as much organic waste material to the soil as possible is now generally recognized. The arrangement of the sludge disposal plant will make it possible to dry all the sludge for fertilizer production, or if it is found that only the surplus activated sludge, with its higher nitrogen content, is worth drying, the digested sludge may be burned. In any event, with the multiple filtration and drying units, complete flexibility of operation is assured.

Flow Measurement

The standing-wave flumes, provided at the outlets to the grit channels to maintain a uniform velocity of flow, are also used to measure the total flow of sewage arriving at the plant. The flow receiving full treatment, including all returned storm water, will also be measured in the 3 D.W.F. flume situated between the storm overflow weir and the comminutors. The meter readings from all these flumes are transmitted electrically to the meter panel in the powerhouse, where they are indicated, integrated, and re-

corded, and the four grit channel readings are also summated and recorded.

Flow of mixed liquor through each aeration unit is measured by means of a Venturi meter, and is indicated on pedestals fixed at the control gallery of the aeration channels.

Returned activated sludge and returned storm water are measured by means of Venturi meters installed in the pipe lines at the sludge pumping stations. The readings are transmitted to a meter panel at the station and are indicated, integrated, and recorded.

The flow of air to the aeration channels is measured by means of orifice plates, with the readings transmitted to a panel in the powerhouse. The total amount of gas used and the amount used by each engine is similarly measured and transmitted to the appropriate panel.

The flow of cooling water for the engines, and of the hot water used for heating the sludge digestion tanks, is also measured and indicated on the appropriate panel.

The above are the principal flow measurements to be made at the works, but in addition there will be a number of minor flow recordings not specifically mentioned.

Conclusion

The Colne Valley Sewerage Scheme provides another example of planned cooperation between the local authorities of a region, to provide and administer an important public health service on lines which it would be both uneconomic and impracticable to achieve by those authorities individually. When put into operation it should not only constitute a great improvement in the sewerage and sewage purification services of the area, but also serve to reduce to a minimum the pollution of rivers which provide part of the domestic water supply for the vast population of Greater London.

Acknowledgments

In conclusion, grateful thanks are expressed to the chairman and members of the Colne Valley Sewerage Board for their permission to present this paper, and to the Board's consulting engineers, Messrs. Sandford Fawcett and Partners, for the use of data and diagrams.

The present paper is based on papers on various aspects of the Colne Valley Sewerage Scheme, presented in 1948 at meetings of the Institution of Sanitary Engineers and of the Institute of Sewage Purification.

DISCUSSION

By R. S. Rankin

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Mr. Brown is to be highly commended for his thorough and able presentation of a comprehensive topic. A studious reading of the paper shows what careful and methodical planning can accomplish in solving a complex problem of considerable magnitude. To attempt to present a critical discussion of the engineering design features of the Colne Valley project would be somewhat presumptuous, but, on the other hand, it is believed that several interesting and instructive comparisons may be made with current practice in the United States.

Some 12 years have elapsed since the Colne Valley project was formally approved, but it should be remembered that England has suffered six years of war and, in addition, there have been two more years of material shortages. All of this must be subtracted from the total elapsed time to arrive at the number of years of unhindered construction.

The design and construction of the

intercepting sewers involved several unique problems. The trunk sewers, approximately 55 miles long and varying in diameter from 15 to 75 in., are connected into local sewer systems serving a total of 14 city, county, urban, and rural districts having 30 existing treatment works and a similar number of pumping stations, most of which are to be eliminated. Associated with the problem of integrating this network into a single system, is the stipulation that the completed intercepting sewer must be sufficiently watertight to prevent the escape of polluted waters into the subsurface water strata, which constitutes the source of water supply for the same tributary area. The rigid adherence to this requirement certainly calls for a high degree of engineering skill.

Considering the capacity of the intercepting sewer, it is interesting to note that the allowance of 6 times the D.W.F. of 40 g.c.d. (Imp.) is equivalent to 288 g.c.d. (U. S.), or about 3 times a D.W.F. of 100 g.c.d. On the basis of this comparison, the Colne Valley sewer is similar to a number of intercepting sewers constructed in this country.

The treatment works has many interesting features, some of which closely parallel designs in this country, but others of which constitute a decided departure from current practice. It is suggested that some of these features be examined in some detail as an illustration of the methods used in solving familiar problems in another country.

One impressive requirement, so it seems to the writer, is that the treatment plant, handling up to 6 D.W.F. without the benefit of any by-pass, is "not to discharge any effluent having a B.O.D. above 20 p.p.m. or suspended solids above 30 p.p.m." Moreover, the effluent must pass the test for putrescibility, which means that a sample incubated at room temperature shall not show evidence of any discoloration or odor. Considering the fact that the dry weather flow of raw sewage will probably contain around 400 p.p.m. B.O.D., a 95 per cent removal is necessary to comply with the requirement. From personal observations, it appears that operators of plants in England and Scotland accept this requirement as to quality of effluent very seriously, and, moreover, endeavor to be always on the safe side by maintaining an average well-nitrified effluent of around 10 p.p.m. B.O.D. This attitude towards an established standard seems remarkable in that no one seems to question it or try to evade it if their works are physically capable of obtaining it. Furthermore, the penalty for evasion usually is nothing more severe than a reprimand from the River authorities, which is usually sufficient. The law is there and it is obeyed—a fine example of wholesome respect, which any country would do well to imitate.

The maintenance of such a high standard at all times usually makes it necessary to provide standby units or spare equipment so that any element of the plant may be removed from service without interference with routine operation. Such a requirement should add appreciably not only to the initial cost of works, but also to the cost of maintenance. However, where any failure might result in contamination of a water supply, such insurance is probably amply justified.

Considering the major plant elements, the grit chamber and comminutor arrangement is similar to designs in this country, although it is believed that this installation of the latter constitutes the first of any size in England. It will be interesting to observe the influence of this example on future works.

The primary sedimentation tanks provide 7½-hr. detention based on dry weather flow, which is, of course, considerably greater than anything pro-

vided in this country. In addition, another 6-hr. detention is provided for storm-water treatment, making a total of 13½-hr. detention based on the dry weather flow. However, the actual volume of tankage provided for primary sedimentation would equal a detention capacity of only 3.6 hr. based on a flow of 100 g.c.d. (U. S.), and that for the storm tanks would equal an additional 2.9 hr., assuming all tanks in service at one time. Thus, tankage volume as such is within limits of practice here.

This comparison obviously does not apply to removals to be obtained in the longer detentions, but, with sewage having an initial concentration of about twice the average American sewage, the longer detention may well be justified if comparable primary effluents are to be obtained. It should also be noted that practice in England requires maximum removal of organic load ahead of biologic treatment, whereas in the U. S. there is a divergence of opinion as to what degree of removal is best.

The Mieder-type sludge removal mechanisms being used in the rectangular primary tanks differ radically from current U. S. types. Their sturdy construction requires only a minimum of maintenance and their traction drives are not exposed to the ice and snow conditions experienced in this country. The additional labor involved in operating this type of mechanism, including the transfer from tank to tank, is apparently justified by local conditions. Possibly increasing labor costs in England might now, or in the foreseeable future, justify greater initial capital expenditures on equipment, thus more nearly paralleling practice in this country.

The design of the aeration tanks is also of particular interest, in that it differs materially from practice in American plants. In this country virtually all plants employing air diffusion are designed to use the spiral flow principle as first developed in Manchester, England. Strangely, the current practice in England is to avoid the spiral flow and instead to use the longitudinal ridge and furrow system. As mentioned by Mr. Brown, tests of both types at the Mogden plant have proven the ridge and furrow design to be slightly superior in some respects and most of the recent designs have adopted it.

The use of the ridge and furrow design requires an entirely different arrangement of diffusers than is common in this country. Current English practice calls for a large number of small diffusers, which, as a result, lend themselves to ease of removal and maintenance.

One outstanding variation from practice here is the volume of sludge returned to the aeration tanks. Here, it is customary to provide for a return averaging around 25 per cent and a maximum of 50 per cent of the flow. In the Colne Valley design, provision is made for the normal return of 65 per cent, with a maximum up to 150 per cent of the dry weather flow. Quantitatively, this represents a wide difference, but it is also interesting to observe that on a per capita basis the two are very close together. A 25 per cent return on a per capita flow of 100 g.p.d. (U. S.) equals 25 gal. (U. S.), whereas 65 per cent return on a per capita flow of 40 g.p.d. (Imp.) equals 31 gal. (U. S.). Of course, the English designs always include provision for reaeration of sludge, a feature seldom found in American plants because experience thus far has shown no particular advantage. It should also be again emphasized that in England a well-nitrified effluent is usually desired, which obviously requires variation in procedure.

The final settling tanks at Colne Valley follow the long-established English practice of upward flow design using relatively small diameter tanks. Just what advantages are ob-

tained from this particular custom is not understood. In this country such designs would be quite costly in comparison with current practice.

In the digestion process, a decided departure from U. S. practice is also noted. A capacity of only 0.9 cu. ft. per capita is provided, which is considerably below current allowances here even though digestion of raw sludge only is contemplated. However, from a comparison of actual practice in sludge digestion in the two countries, this rather limited capacity takes on a different aspect. In the first place, in the representative English plants sludge is not stored in active digestion tanks for weeks or months, as is common in this country, but the requisite amount of digested material is withdrawn daily and placed either on sludge beds, in lagoons, or in large-capacity holding tanks. Secondly, current practice there does not permit digestion to proceed as far as it usually does in this country. Here, it is usually considered desirable to digest upwards of 60 to 65 per cent of the initial volatile matter, thereby obtaining maximum gas yield and practical elimination of odors in the digested sludge. In England, it is not uncommon to note from reports that sludge is discharged with no more than 35 to 45 per cent of the volatile matter digested, with consequent lower gas production and likelihood of the sludge being more odorous.

These two factors combined do permit a considerable reduction in digestion capacity, although obviously a larger volume of digested sludge must be handled. Where sludge is returned to the soil and where odors from partially digested sludge are not objectionable, this increase in volume is often desirable. However, this method of operation seems to necessitate closer daily control than is customary here. In the case of the Colne Valley project, instead of beds, lagoons, or storage tanks, vacuum filters will be called upon to take the daily load, so it will be interesting to observe the effect of these differences.

Two other features deserve special comment, one of these being plant instrumentation. It appears that in England, instrumentation has attained a high degree of perfection as regards quality, utility, and dependability, and the Colne Valley project constitutes an excellent example. These qualities are certainly most essential in a sewage treatment plant; it is an example which this country can surely afford to follow.

The other feature deserving comment is the dual-fuel engine installation. This type of engine, first developed in 1937 in England, seems to be accepted there for all gas engine installations and the one at Colne Valley is of the most modern design. It is the logical type for plants which desire to obtain maximum power output when using digester gas as a fuel, as it virtually assures independence from outside power sources, with costly standby charges.

The operation of the vacuum filters and final sludge disposal, either by drying alone or with incineration, will certainly be watched with interest by other British operators, as it is believed this constitutes the first installation of this type. In England, incidentally, the usual chemical sludge conditioners are either not available or very expensive. In this country, fortunately, an ample supply of ferric chloride is usually available so that one of their problems is non-existent here.

Many other interesting comparisons will be noted in Mr. Brown's paper. The paper as a whole does demonstrate an important principle; namely, that a knowledge of the technical experience of England, when combined with that of America, is certain to broaden the skill of both countries and, eventually, it will result in better and more efficient plants for all.

TRAINING SEWAGE WORKS OPERATORS IN THE UNITED STATES *

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1948 Training Program

A brief review of short course training programs offered in the United States in 1947 was made by the writer as a part of the Engineering Section Project of the American Public Health Association. The information obtained was such that it seemed desirable to make a study of training programs on the basis of more complete and detailed information for the year 1948.

After discussions, it was agreed that the Federation of Sewage Works Associations and the Engineering Section Project would cooperate in the gathering of 1948 data through a questionnaire form in which it was proposed to obtain information on the following:

1. Type of course given in 1948, together with the length of instruction period.
2. Number of times each type of course was given during the year.
3. The sponsorship and support of short course training.
4. The location where such courses were held.
5. The frequency of the planned training program.
6. The method of holding short courses, either separately or in combination with other training.
7. The numbers and kinds of personnel trained during 1948.
8. The status of state requirements for certification or licensure.
9. The practice of allowing credit for short course training as a qualification for certification or licensure.
10. The year when the several types of short course training were first started.
11. The cost of enrollment to the trainee.
12. Details of the course offered.
13. Pertinent information concerning the names of sponsoring agencies, universities, course directors, and the conduct of the training program.

The questionnaire was sent to the state sanitary engineer of each state, to the territorial health department engineers in Alaska and Hawaii, and to the district health department engineer in the District of Columbia. It was assumed that these engineers would have the necessary data in their own files or would obtain the data from cooperating sponsors.

Responses to the questionnaire were received from 50 of the 51 addressees. Several respondents made no attempt to fill in the questionnaire, although the return letter offered information requested by the questionnaire, making it necessary to interpret the letter reply in terms of the questionnaire item. In nine instances, where no course was offered in 1948, the questionnaire was returned without information supplementing that fact. Thus, positive information concerning the dates of first training programs and the status of requirements for certification is lacking for some states. There were a few returns from states where training was offered in which every question was answered so that interpretation was unnecessary.

In all, 26 states reported short course training programs of some character

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TABLE I.—Summary of Short Course Training Programs Offered in the United States, its Territories, and District of Columbia During 1948

Type of Information	Number by Type			
	State-Wide	State Regional	State Local	Univ. Ext.
A. Training schools held:[1]				
1. By type of school	18	9	1	1
2. By sessions of one type	18	39[2]	1	5
B. Length of course:				
1. Range in 8-hr. days	1–10	1–15	3½	—
C. Sponsorship:				
1. State health dept.	20	9	0	1
2. Local health dept.	0	1	0	0
3. Sewage wks. org.	15	7	0	1
4. University	18	8	0	1
5. Local sewage wks. dept.	3	0	1	0
6. Other[3]	6	3	1	0
D. Training location:				
1. University	15	3	0	1
2. Public school	0	1	0	0
3. Other location	4	5	1	0
E. Frequency of training:				
1. Annual	18	2	0	0
2. Biennial	0	1[4]	0	0
3. Semi-annual	0	1	0	0
4. Continuous itinerant	0	0	0	0
5. Intermittent	0	4	0	0
6. One only	0	1	0	0

[1] 26 states sponsored training programs.
[2] One state reported 180 sessions requiring 22 days; not included in total.
[3] Includes municipal leagues, state or municipal public school boards, city governments, etc.
[4] One state on biennial basis gave course in 1947 and in 1949; data not included in totals.

All schools are referred to according to type. A school of one type may be repeated more than once per year, and these meetings have been interpreted as sessions of the one type of school—that is, one regional-type school may have been held in three places during the year as three sessions of one regional-type school.

Type and Duration

A summary of the training program is presented in Table I. Eighteen state-wide schools were given by 20 states. (The Rocky Mountain states of Colorado, New Mexico, and Wyoming combine their efforts into one school held at Denver University each year.) Training time of the state schools ranges from 1 to 10 days, the distribution being as follows: 1 day, 4; 2 days, 2; 2½ days, 1; 3 days, 3; 4 days, 2; 5 days, 5; and 10 days, 1. Thus, the preponderance of state-wide schools is of 5-day or less duration. The regional schools are usually 2 days or less, the distribution being: 1 day, 3; 2 days, 3; 4 days, 1; 6 days, 1; and 15 days, 1. Actually the 15-day school is one which extends over a long period of time. Classes at this school are held at Niagara University, New York, each Saturday morning for 30 weeks.

Sponsorship and Frequency

Every state-wide and state regional school given had the sponsorship of a state health department. Of the state-wide schools, one was conducted alone, the sponsorship of two was shared with a university, and the balance were sponsored jointly with three or more

groups. Regional school sponsorship was shared in one instance with a sewage works organization, in another with a university, and the balance were jointly sponsored by three or more groups.

The majority of all training schools was held on a university or college campus, and one regional training school was held at a public school. Otherwise, the short courses took place on state or municipal premises.

All state-wide schools are conducted on an annual basis, whereas the regional schools are of variable frequency. Oklahoma uses a quarterly system for its regional schools; Wisconsin and New York use a biennial system; Florida, Indiana, and Michigan use an intermittent system, scheduling schools as may be needed. Virginia has had one school only in recent years.

The one localized school reported is carried on at Los Angeles, Calif. The characteristics of that school have been reported (see *Sewage Works Journal*, 21, 1, 128; Jan., 1949).

Separate vs. *Combined*

There has been some interest in the pros and cons of separate versus combined short course training schools. In sparsely settled areas and in places where the water works men and sewage works operators are frequently on one staff, it is more feasible to hold combined schools. The returns from the questionnaire indicated that there were at least 7 state schools, 6 regional schools, and 1 localized school held solely for training in sewage works operation and maintenance. On the other hand, 13 state and 3 regional schools offered combined water and sewage works training. Considering the geographical location of these schools, it appears that the North Central, Southwest, and Mountain states prefer combined schools; 4 of 6 Southern states prefer combined schools, the Central states are nearly evenly divided, and the East and West hold schools uniformly on a separate basis.

The tabulation of the distribution between separate and combined schools on a geographical basis is as follows:

Area	Total	Separate	Combined
Eastern	5	5	0
Southern	6	2	4
Central	5	3	2
North Central	2	0	2
Rocky Mountain	4	0	4
West Coast	2	2	0
Southwest	2	0	2

Enrollment

The returns on school enrollment were not complete enough to be satisfactory. A breakdown by types of personnel attending was obtained from 17 states, representing 15 state-wide courses, 6 regional courses, and one university extension correspondence course. The data indicate that the following numbers received training:

Type of Personnel	Type of School				
	State-Wide	Regional	Local	Univ. Ext.	All Types
Operators	681	343	NR	62	1,086+
Superintendents	262	131	NR	0	393+
Public Health Personnel	138	68	NR	0	206+
Others	94	133	NR	0	227+
Total[1]	1,235	703	NR	62	2,000+

[1] Includes unsegregated totals of reported attendance at two courses.

Of the 41 states giving a positive answer on the status of certification and licensing, 25 have no provision of any kind, 11 have voluntary certification or approval, and 4 have mandatory certification, licensing, or approval by statute enforced by the state health department. The latter states are Connecticut, New Jersey, New York, and Texas. Those acting on a voluntary basis include California, Florida, Georgia, Illinois, Louisiana, Michigan, North Dakota, Ohio, Oklahoma, South Carolina, and West Virginia. Approval or certification in these states is granted by the state sewage works organization in four states (California, Georgia, Louisiana, and North Dakota), the State Health Department or State Board of Health in five states (Florida, Ohio, Oklahoma, South Carolina, and West Virginia), and the State Department of Public Health and the Sanitary Water Board in one (Illinois).

Certification Credit

Opinion seems to be divided on the point of crediting short school training toward certification qualification. In the case of the 20 states replying to this question, state-wide school training is credited by 8 and not accepted by 9. Regional school training counts in 4 and is not counted in 3 states. Oklahoma allows credit for localized schools, but Iowa doesn't. Michigan accepts university extension training.

States reporting having had a state-wide short course at some time numbered 23. Iowa, Kansas, New Jersey, Oklahoma, and Texas each held their first courses in the 1920's, Oklahoma seemingly holding first honors with a record of a course given in 1921. Georgia, Louisiana, Minnesota, Montana, New York, Pennsylvania, and Wisconsin began state-wide courses in the 1930's. Colorado, New Mexico, and Wyoming began their state-sponsored school in 1941, and were followed by Alabama, Connecticut, Florida, Nebraska, Ohio, and South Carolina. Idaho, Missouri, and New Hampshire report that no state-wide short schools have ever been held.

Starting with Oklahoma in 1925, nine states have reported regional schools. New York began this type of school in 1939, and the balance were started in the 1940's in Florida, Indiana, Iowa, Michigan, Pennsylvania, Washington, and Wisconsin. Idaho, Missouri, and New Hampshire reported that no short school of any type has been held, although Missouri plans to provide extension training for sewage works operators some time in the near future.

Costs to Trainees

Enrollment costs to the trainee were reported by 19 of the 20 states sponsoring 1948 state-wide schools, by 8 of 9 states sponsoring state regional schools, and for the university extension course given in Iowa. Distribution of the enrollment fee, which ranges up to $15 for state-wide schools, and up to $50 for regional schools, is shown in the following tabulation:

Cost to Trainee ($)	Number by Type of School		
	State-Wide	State Regional	Univ. Ext.
0	4	5	—
1	—	1	—
2	7	—	—
3	2	—	—
5	2	—	—
6	—	—	1[1]
7	—	1	—
8	1	—	—
10	1	—	—
15	1	—	—
50	—	1	—

[1] One full course of 12 lessons at $0.50 per lesson.

The localized training program at Los Angeles, California, is on-the-job training for which time is allowed.

A check has been made on the status of training in 1948 as compared to that reported in 1947. Of 38 states reporting in 1947, only 12 offered short course training; but of the same 38 states, 21 offered training in 1948, 10 offered training in both years, 2 in 1947 only, 11 in 1948 only, and 15 in neither year.

As for the 1949 plans, 25 states plan to continue annual courses. Mississippi expects to begin short course training in the "near future." North Dakota and Wisconsin have held courses in 1949. South Dakota plans training for 1950 and West Virginia will start at the "earliest possible time." Missouri has held extension course training for water works operators in the past and hopes to establish the same kind of training for sewage works operators within the next two years.

Course Content

The respondents to the 1948 questionnaire furnished information which has been used to analyze the subject matter presented in 21 training school programs offered by 21 states. Course content has been interpreted and consolidated. It was not always clear from the lecture title just how much a given topic was discussed; therefore, it is conceivable that the writer is guilty of both omission and commission in crediting to the school certain topical material. Some of the outlines submitted were for 1949 schools held early in the year, so the present discussion should not be misconstrued as 1948 training exclusively. It must be said, however, that the outlines were submitted as a representation of 1948 training.

In the summary no attempt has been made to differentiate between the intensity of treatment of subject matter offered in any of the types of schools held. Such differentiations will be analyzed in some detail in later discussion. Programs of 16 state-wide type schools, 4 regional-type schools, and one local-type school have been summarized by subject matter in Table II.

The amazing feature of the summary is the vast array of particular topics

TABLE II.—Summary of Content in 21 Training Program Outlines of Current (1948) Sewage Works Short Courses in the United States

	Subject Matter		Number Offering
1.	Arithmetic		6
2.	Hydraulics		4
3.	Sewage characteristics (gen.)		7
4.	Sewage works vocabulary		4
5.	Sewage bacteriology		7
6.	Sewage chemistry		11
7.	Sewage biology		4
8.	Sewage physics		1
9.	Lab. tests, technics, demon., pract.		14
10.	Sewage purif., treat.; theory and prin.		7
11.	Sewage treat., proc. and methods (gen.)		7
12.	Treatment	Proc., oper., maint. (gen.)	7
13.		Screens, grit chambers, etc.	9
14.		Sedimentation units	8
15.		Imhoff tanks	7
16.		Activated sludge plants	9
17.		Septic tanks	2
18.		Trickling, high-rate filters	10
19.		Contact beds	4
20.		Sand filters	2
21.		Land disp. beds or land irrig.	3
22.		Chemical flocculation	2
23.		Chlorination	11
24.		Odor control	1
25.		Incineration	1
26.		Sludge dig., disp. prob.	14
27.	Design of systems or plants		7
28.	Construction	System or plant (gen.)	4
29.		Plants	2
30.		Sewers	4
31.	Sewer system	Maintenance	7
32.		Repair	1
33.		Mosquito breeding	1
34.	Plant	Oper., maint. and rep. (gen.)	4
35.		Pumping problems	9
36.		Equipment, electrical	5
37.		Equipment, mechanical	2
38.		Metering, measurement	4
39.		Plumb., cross-conn., etc.	3
40.		Housekeeping	2
41.		Devices and gadgets	1
42.		Prot. and safety meas.	3
43.	Industrial waste treatment		5
44.	Stream poll.	Stream sanit. (gen.)	9
45.		Deg. of treatment	1
46.	State requirements and programs		5
47.	Status of treatment (gen.)		2
48.	Operator responsibilities		6
49.	Training and qual. of operators		7
50.	Health significance, disease		3
51.	Planning and admin. for sewage works		3
52.	Ordinances		3
53.	Financing	General	1
54.		Rates	2
55.		Treatment costs (gen.)	1
56.	Sewage works records		8
57.	Operators' discussion of problems		11
58.	Demonstration and field inspection		6
59.	Films		6
60.	Public relations		3

that have been offered. No less than 60 topics are listed, and even these represent a condensation of topics having similarity. For instance, no attempt was made to subdivide the several tangential discussions arising out of the handling of sludge digestion and disposal problems, or the many varied approaches to the subject of laboratory tests, testing procedures, and practice. It is not surprising, in view of the variation, that no one subject matter is common to every training program. The subjects which receive treatment in 50 per cent or more of the programs include laboratory testing, sludge digestion or disposal problems, sewage chemistry, trickling and/or high-rate filters, chlorination, and operators' discussions.

The topics discussed in 25 to 50 per cent of the programs include arithmetic; general sewage characteristics; sewage bacteriology; theory and/or principles of sewage purification and treatment; general aspects of sewage treatment processes and methods; general aspects of operation and maintenance of sewage treatment processes; specific problems related to primary treatment, including screens, grit chambers, grease removal, sedimentation units, and Imhoff tanks; general discussions of plant design; sewer system maintenance; pumping problems; stream pollution problems; operator responsibilities; training and qualifications of operators; records and record keeping; field inspection trips; and films about sewage works operation and stream sanitation.

The balance of the subject matter appears sporadically in from 1 to 5 programs. It was a distinct shock to find that the training opportunity was seldom used to discuss such important topics as public relations, health significance and disease transmission, state requirements, industrial waste treatment, and hydraulics. All of these topics are in training areas contributing to successful operation and maintenance of sewage works and can be no less taken for granted than laboratory testing, record keeping, or sewage chemistry. In fact these latter might be better undertaken if the operator had a sound background of the former. One probable explanation of the lack of current training in the underemphasized topics could be that long established programs have presented the subjects before, and will again as operators attend a new series of schools; and that newly established training will offer such topics early in future programs.

State-Wide Schools

Inasmuch as Oklahoma and Texas have offered training programs since the early 1920's, their 1948 programs are examined in more detail. The Oklahoma state-wide school is held jointly for water and sewage works men. It is sponsored by the Oklahoma Agricultural & Mechanical College in cooperation with the Oklahoma Water and Sewage Works Conference, the Trade and Industrial Division of the State Department of Education, the Oklahoma State Health Department, and the Southwest Section, American Water Works Association. The program is held annually. The short course staff was comprised of staff members of Oklahoma A. & M. College, the State Health Departments of Oklahoma and Texas, water department superintendents, consulting engineers, State and U. S. Geological Survey representatives, and representatives of other colleges. Equipment manufacturers supplied demonstration material.

Instruction was offered to the sewage works men under the general caption "Water and Sewage Works Operation," and certificates were presented to each person who attended all of the group sessions held during a 5-day period, Monday through Friday. The program itself was quite obviously directed to the multiple interests of the

men; of the 22 discussions held only 7 were directed at the problems of sewage works. Ten might be termed of corollary interest to the sewage works man, and certainly were of interest and value to the man who might be responsible for both water and sewage works. The balance were exclusively for water works men.

The Texas program is the outgrowth of 30 years of short course training experience. Water works schools began before 1920, but sewage works schools were not included until 1926. The combined "Water and Sewerage Short School" is held at Texas Agricultural & Mechanical College annually as a cooperative effort of the Texas State Board of Health, the Southwest Section, AWWA, the State Board for Vocational Education, and the college. The program is composed of general and sectional meetings. The sewage works section has sessions known as "Grade C," and "Grade B and A." In 1948, one general session was held at which all water and sewage works men attended. The Grade C men attended 16 separate lectures; the Grade A and B men attended 15 separate lectures; then all grades met for three lectures. Subject matter of every session was directed toward sewage works problems. Much of the subject matter appears common to both the C Group and the A and B Group sessions, but apparently the same material receives more intensive treatment before the latter group. For example, the first group discusses "Filter Operating Problems and Correction," while the latter takes up "Trickling Filter Loading" and "Application and Limitations of Sewage Filters." The instruction in the Texas school shows every evidence of long planning and elicits the cooperation of recognized specialists both in the state and elsewhere, from state and local health departments, plants, industry, colleges and universities, consulting engineering firms and others.

State-wide schools range in comprehensive coverage of subject matter and it is difficult to say that any one method of presentation is superior to any other; however, it does seem that the schools of some duration offer a more substantial training than do the schools of shorter length. Ohio's short course training (first held in 1948) offers evidence that operators do get some worthwhile training from such courses. Of the 39 plant operators registered for the course, 35 took the examination and 60 per cent of these received a grade above 70 per cent. The keynote of Ohio's instruction was the "how" rather than the involved theoretical "why." The course was presented in three divisions —problems, processes, and chemistry and analysis.

Regional-Type Schools

The regional-type schools appear to have a much wider variation of treatment than do the state schools. The impression has been gained, perhaps erroneously, that certain of the regional schools are little more than conferences, and that such schools should not be classified as short courses. However, there are some excellent examples of well-planned and executed regional training programs. Niagara University (New York) offers an intensive training in fundamentals. Chemistry, arithmetic, vocabulary, chemicals and their properties and application, physics, elements of organic chemistry, composition of sewage, sewage treatment processes, hydraulics, the nitrogen cycle, biology, bacteriology, and disinfection, all receive attention in the course of 30 periods held on successive Saturday mornings. This course for Grade III operators has been carefully arranged with the approval of the state department of health. The training is accepted for credit toward state qualification as an operator.

The Indiana State Health Depart-

ment and Purdue University abandoned a 1-week course held at the university in favor of a regional course to be held when and where needed 1 day a week over a 6-week period. Material for each day's session (5 lectures) is prepared in outline form and trainees have a copy to take back with them for reference and further study. For example, the lecture on Imhoff tank operation discusses description of tank, operation, why the operation procedures are necessary, and tests for determining efficiency of operation. Certainly this type of training is useful and conducive to a better understanding of sewage works operation.

Regional schools in Oklahoma are established on a quarterly basis; in the course of 4 one-day meetings in each of the State districts, the subject matter of one is repeated in all of the districts. There seems to be a tendency in these regional meetings toward the conference type of meeting rather than short course training.

Sample material illustrative of the extension course work such as is held in Iowa, Texas, Oklahoma, and Michigan was not supplied. Oklahoma and Texas take the lecture or work of the course to the operator by means of itinerant instruction. Iowa makes courses available in the form of lessons which the trainee studies. A meeting was held at Iowa State College in 1948, at which Professor W. E. Galligan and Iowa State Health Department engineers lectured on the several lessons given in the extension correspondence course.

Local Schools

The only current example of a local training course available to the writer is that conducted by the Los Angeles City Department of Public Works. As this course has been previously discussed, there is no need to pursue it further here.

Ten years ago the writer carried on a localized training program in San Joaquin County, Calif. The training course consisted of sessions of 2 hours, each given one evening a week for 6 successive weeks. It was devoted entirely to fundamentals of sewage treatment. There is no question but that the basic instruction so given has had lasting benefits, both for the operator and for the communities in which the treatment plants were located. Specifically, better plant operation, improved public relations, increased compliance with state and local requirements, and an understanding of the other fellow's problem evolved from that training. On-the-job and localized training deserves far more attention from health and public works departments than it is now receiving. A certain move in this field is indicated by the effort of several state engineers to discuss plant problems with the operators during extended plant visits.

Conclusions

The liberty is taken of drawing certain conclusions from a study of short course training in the United States, as follows:

1. Training facilities have improved over those offered in 1947, but still do not satisfy the need for short course training in the United States.

2. Those state-wide training course outlines examined in detail exhibit an unusual variety of subject matter indicative of a wide range of viewpoints as to what may be important in sewage works design, construction, operation, and maintenance, but on the whole are constructive and valuable to the trainee.

3. Insufficient attention is focused in training course content on the important factors of public relations, relationship of sewerage and sewage treatment to the promotion of health and the prevention of disease, industrial waste treatment, and state requirements for efficient treatment and operation.

4. Regional-type schools are well developed in a few states, but could stand review and additional planning in others.

5. There is not enough evidence to indicate that localized schools are being developed as they should be. If they are, state health departments should have knowledge of them.

6. Extension courses appear to have real value in the few states where they have been offered.

7. Whenever water and sewage works schools are held jointly, as a matter of expediency, a special effort should be made to schedule sewage works sessions separately for those whose primary training is to be in the sewage works field.

8. The policy of allowing credit toward operator qualification for certification or licensure should receive further study, with a view toward the achievement of uniform requirements for such certification and the establishment of standards of short course work reciprocal among the several states.

9. The policy of mandatory state licensure or certification merits detailed study. In 4 states, certification, approval, or licensure of operators is now mandatory; in 11 others, voluntary.

10. The practice of cooperative sponsorship of schools by departments of health, universities, sewage works organizations, municipal and state governmental agencies, and public officials organizations is laudible, and should be continued and expanded wherever possible.

11. State health departments are justified in allocating staff time to the promulgation of training programs to meet state needs by such evidence as the number of sewage works personnel trained presently, by the evidence of increased national interest in clean streams, and by the indication of increased operator proficiency shown in statements covering the value of 1948 training programs in the several states.

Summary

Information concerning sewage works short course training in the United States has been compiled and analyzed. The information was obtained by questionnaires sent to all state sanitary engineers. The analysis is presented in two parts—1948 training program and course content.

Short course training in 1948 was reported by 26 states. Training for more than 2,000 persons was provided by 18 state-wide schools, 9 regional-type schools, 1 state localized-type school, and 1 university extension correspondence course. Four states have mandatory certification and 11 others offer voluntary certification. Both state-wide and regional-type schools were established in the 1920's, but 3 states have never had short course training programs. Training was planned in 1949 by 25 states.

Course content deals with subject matter under 60 topical headings with major emphasis on laboratory techniques, chemistry, sludge digestion and disposal problems, filters, chlorination, and operators' discussions. Lacking in emphasis are such topics as public relations, relation of sewage to health and disease transmission, state requirements, and industrial waste treatment.

Acknowledgments

The writer is indebted to W. H. Wisely, Executive Secretary, Federation of Sewage Works Associations, for his advice and assistance in the preparation of the questionnaire. The excellent cooperation of the state sanitary engineers who furnished the data on which this paper is based is greatly appreciated.

DISCUSSION

By Bernard S. Bush

District Engineer, State Dept. of Health, Wilkes-Barre, Pa.

It is impossible to present a true discussion of Professor Ingram's paper, inasmuch as it is non-controversial in nature. It is, however, an exceedingly well-prepared consolidation of facts clearly setting forth achievements attained to date by way of training the operator. Under "Conclusions," Professor Ingram does offer an opportunity for one to assume an opposite point of view, but to do so would be an error, as his items of deficiencies and laudable attainments are logical.

To those who have not experienced the difficulties of training operators, the statistics may appear such that they can be looked at with pride. In considering, however, that almost three decades have passed since conception of the first operator's training course, that there are presently several thousand sewage treatment plants in the United States, and that the entire country is now in the midst of a clean streams program, the fact must be faced that the surface has been merely scratched in providing means for training operators.

In spite of the fact that many leaders in the field have expended much effort toward training the operator, uniform concerted efforts have been lacking. Increased interest must be aroused, therefore, in members of professional associations and governmental agencies.

Professor Ingram aptly points out the omission of important subject matters such as public relations, prevention of disease, etc., in most of the courses. These subjects will undoubtedly develop in the natural course of program growth. More important, however, is the need for responsible agencies to coordinate and correlate this work, which will lead to the establishment of basic state-wide schools on a generally uniform plan, with gradual expansion of regional schools augmenting basic courses.

To show that both types of school are popular and accepted with eagerness by the operator, the results of experiences in Pennsylvania are briefly reviewed. In the spring of 1945, under sponsorship of the Pennsylvania Sewage Works Association, the Pennsylvania Department of Health, and the Sewage Works Operators of Southeastern Pennsylvania, in cooperation with St. Joseph's College in Philadelphia, and the Engineering Science and Management War Training Program, a short course was held at the college each Wednesday afternoon for 7 consecutive weeks. The course comprised lectures and laboratory work. The latter originally was devised to give each enrollee an opportunity to get into the laboratory and perform various tests himself. On this and other occasions it has been found that such procedure in laboratory work is practically impossible unless the groups are relatively small. In spite of limited laboratory facilities, this was a highly successful course with an enrollment of 65 students, 64 of whom completed the course with an average hourly attendance of 99.1 per cent.

In 1946 the Pennsylvania Sewage Works Association published the context of the course in two books, one comprising the lectures and the other the laboratory procedures. It may be interesting to note that, since publication, the Association has disposed of 500 copies of the "Lectures" and 750 copies of the "Laboratory Guide." It has never been claimed that the "Guide" is in any way, shape, or form a textbook, but contains only analyti-

cal procedures set up in cook-book style for ease of application.

In June, 1948, under sponsorship of the Pennsylvania State College, the Pennsylvania Department of Health, and the Pennsylvania Sewage and Industrial Wastes Association, a state-wide training school was established at State College. It is a 5-day school, with two courses, C and B, offered. As the designation implies, the C course is elementary and the B intermediate. The school was well attended for its first year, with a total enrollment of 50. In 1949 the school was repeated, offering the C and B courses as well as an advanced course designated as A. Total enrollment was 53. It is felt that these courses were successful and from the reaction of the students, as well as instructors, there is every reason to believe that future courses will be improved. Particular emphasis is placed on the fact that in Pennsylvania the aim is to offer training for sewage plant operators as such and to carefully avoid creating the impression that successful completion of courses would change a sewage plant operator into a chemist or sanitary engineer.

The Sewage Works Operators of Southeastern Pennsylvania have for a number of years held 1-day regional meetings. Recently, they have changed from the inspection-type meeting, to which Professor Ingram refers as "conference," and are periodically conducting short course schools that combine the desirable features of inspection and academic study through which individuals in small groups may have an opportunity of developing laboratory technique. The activities of this group are comparable to regional schools and vividly bring out the fact that the annual course at State College is not sufficient and although it provides basic state-wide training, the need for expansion through regional schools is obvious.

There are two major problems confronting us—first, the conducting of coordinated state-wide and regional schools, under the same general administration, with courses which are practical for every type of operator; secondly, the convincing of municipal officials of the need for operator training to the end that these officials require such training and provide operators with the necessary free time and financial assistance.

Training the operator is not as easy as it may sound. In the trades there is opportunity for apprenticeship, but in sewage treatment plant operation such apprenticeship is not practical. However, on-the-job training is of much value. Therefore, the operator should not be looked upon as a tradesman, but rather as a trained technician. Too often a well-designed and well-constructed sewage treatment plant has been placed in operation and turned over to an inexperienced operator, with the result that before long serious difficulties arise. The plant becomes a forgotten unit of the municipality, tolerated but not appreciated.

It is imperative that agencies such as the Federation, Member Associations, State Health Departments, and Municipal Officials, cooperating with educational institutions, give more time, thought, and effort to the continuance of those training schools already begun and to their expansion, to the end that the great need for providing trained sewage works operators be met. On the whole, municipal officials throughout the United States are exceedingly lax in recognizing their obligations in this matter. It is our duty and obligation to present this problem and impress upon these officials their responsibility.

GANDILLON'S COMPLETE MUNICIPAL SEWERAGE SYSTEM *

By A. Szniolis

Translated and Condensed by Conrad P. Straub

In 1914 a municipal sewerage system based on a new principle was constructed in the village of St. George, France, located on the Seine River, about 9 miles above Paris. This system differs from conventional systems in that the sewers are cleansed with air. Designed by Pierre Gandillon, the system enables all types of wastes, which may be directly or indirectly harmful from the standpoint of health, to be discharged into a tight system of sewers, from which they are evacuated to a central plant for treatment.

The topography of St. George played an important role in the development of the Gandillon system, as the most built-up section of the village is in the valley of the Seine River, on level terrain slightly higher than the river level. Under these conditions the construction of combined sewers of large diameter and suitable slope, with the necessary pumping stations, could be realized only at a cost which the village could not afford. Various modifications of known sewerage systems were examined, but no suitable solutions were found until that suggested by Gandillon was considered.

Gandillon's sewerage system is a separate system. The storm drains, being similar to systems found in normal practice, are not discussed here. However, the system for carrying domestic wastes is described in detail. It has been installed in other French cities, notably Dieppe, Rouen, Nevers, and Fort-de-France (Martinique), which had a population of 60,000, as well as in several smaller communities.

Originally, the sewerage system was not adapted to the removal of refuse and organic wastes, but served exclusively for the removal of sewage. The following detailed description is concerned with the latest modifications as reported in 1934.

Description

The sewerage appurtenances may be divided into three parts: (1) household facilities, (2) sewer network (the street sewers, sub-stations on the collectors, collectors, and pumping station), and (3) sewerage treatment and recovery plant (see Figure 1).

* From the Polish article "Uniwersalna Kanalizacja Miejska Systemu inz. P. Gandillona," which appeared in *Zdrowie Publiczne*, No. 3 (1934).

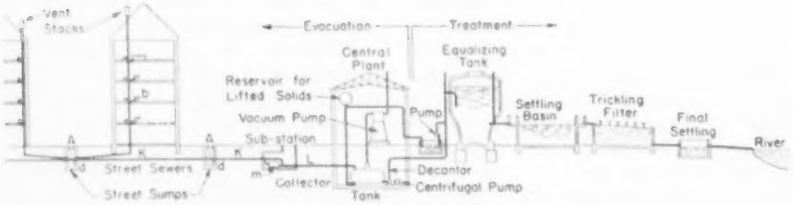

FIGURE 1.—Gandillon's vacuum sewerage system.

Household Appurtenances

In general, the household appurtenances are similar to those in use elsewhere. House drains are the same. All sanitary facilities, such as water closets, sinks, wash basins, bath tubs, etc., are connected to the vertical riser pipes in the usual manner. One piece of equipment differs, and that is the kitchen sink, which is adapted to the removal of organic wastes and rubbish. (Mineral sweepings, slag, papers, and other wastes that do not decompose readily are not to be discharged into the sewers through the sinks—but this regulation is not complied with. Such refuse is supposed to be collected in buckets and carted off by the municipal refuse collectors.)

A section through the Lancery type of sink is shown in Figure 2. The unit consists of a rectangular sink and a poured base in the shape of a reservoir, which is equipped with a siphon trap at the bottom and connected to a vertical riser pipe. Inside the base is a tipping bucket with a capacity of 3.1 gal. Liquid flowing out of the sink passes directly into the tipping bucket, which on filling tips automatically and discharges its contents into the drain pipe (siphon chamber) and then into the vertical riser pipe. The tipping bucket also serves as a receptacle for organic wastes and rubbish, the brass screen in the sink being lifted out and the wastes dropped into the tipping bucket. When the tipping bucket fills,

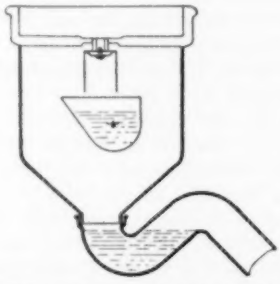

FIGURE 2.—Section through kitchen sink.

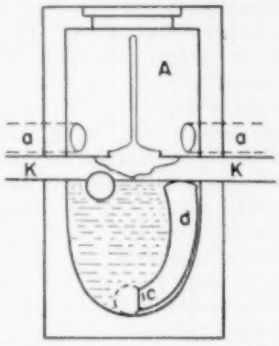

FIGURE 3.—Section through street sump.

it tips and empties rapidly and the wastes collected therein flow into the sewer. Because of the appreciable quantity of liquid discharged with each tip of the bucket, the house sewers rarely clog.

The soil stacks, to which all sewer lines are connected, are made of 8-in. diameter cement-asbestos pipe. House and connecting sewers are likewise of 8-in. diameter and are laid at a slope of 2 to 3 per cent. Vent stacks are carried above roof level and are equipped with ventilators.

Sewer Network

The street sewers are of 8-in. diameter, cast-iron, bell and spigot pipe, and of tight construction with jute and lead joints. All street sewers are laid at a slope of 0.1 per cent. Individual house sewers are not connected directly to the street sewers, but to a sump, each sump serving 3 or 4 homes. A section through one of the sumps is shown in Figure 3.

Sump A is built of concrete with a paraboloidal shaped bottom and a normal manhole entrance. The street sewer, K—K, passes through the center of the sump. At each sump the sewer is provided with an extension arm, d, whose open end, c, reaches almost to the bottom of the sump. House sewers, a—a, are brought to the sump from four sides, with the invert eleva-

tion somewhat higher than the invert of the street sewer, K—K. There are usually from 10 to 15 sumps along a street sewer.

The street sewers are led to a point through which the main collector passes, and a sub-station serving 5 or 6 street sewers is located at the junction. Each sub-station is constructed below street level and contains special valves and equipment for connecting the street sewer to the main collector. There are 6 sub-stations on a main collector 8,528 ft. long.

Street sewers are connected to the main collectors as shown in Figure 4, in which K—K represents the lower portion of the street sewer, L indicates the collector, Z the valves, W clean-out hole, and m a special device through which the wastes flow from the street sewers to the collector. When the street sewers are being cleaned, valves Z are used to connect the street sewer directly to the collector.

The collector is of 14- to 16-in. diameter cast iron. The upper end of the collector originates at the first sub-station, and the lower end terminates in two cylindrical tanks located at the treatment plant. Each tank has a capacity of approximately 4,000 gal. and is divided in half by means of a perforated baffle.

Method of Operation

The sewer system may function in two different ways: (a) the period of gravitational flow, and (b) the period of sewer cleansing.

Normal Flow

Gravitational flow occurs during approximately 22 hr. per day. Wastes and rubbish from homes discharge through the house sewers into the street sumps, A, and fill these to the level of the street sewer invert. Larger solids and rubbish collect in the lower portion of the sumps. The excess liquid flows through the extension, d, into the street sewer and toward the sub-station, where it passes through

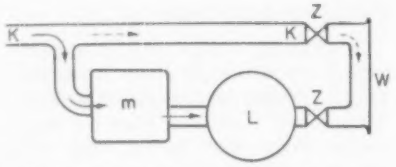

FIGURE 4.—Method of connecting street sewer to collector.

the device m and flows through the collector to the main plant. If larger solids get into the street sewer with the liquid, they either will flow with the liquid to the end of the collector or will settle in the sewer and accumulate there. Even in the latter case, the liquid will trickle through the deposited solids and flow to the above-mentioned tanks. At the treatment plant, the coarser solids settle in the first compartment of the tank and the liquid passes through the openings in the baffle to the second compartment. The liquid is pumped to the following units of the treatment plant by means of float-controlled centrifugal pumps. In the above manner, the sewer system operates practically throughout the entire day without the use of mechanical equipment.

Sewer Cleansing

Once each day, usually for a period of 2 to 2½ hr., two vacuum pumps are operated for the purpose of evacuating the two aforementioned tanks and the collectors directly connected to them. In a few minutes a vacuum of 17.7 to 23.6 in. of mercury develops in the tanks and collectors (in other words, the absolute pressure falls from 1 atmosphere to between 0.4 and 0.2 atmospheres).

Due to the special construction of device m (shown in Figure 4), the vacuum created does not affect the side sewers, but remains exclusively in the collector. During this time, two laborers go to each sub-station and connect each of the street sewers with the collector by opening the valves Z—Z. In the newer sub-stations the laborer does

not have to enter the underground chamber, but opens a small sump located at street level and presses, in rotation, a series of pedals, which connect the street sewers to the collector. A vacuum develops in the street sewers and all material found in the first sump is removed, then that in the second is removed, etc.

To prevent the loss of vacuum in the street sewers through the sumps, a rubber-covered wooden ball, which normally floats on the surface of the liquid, drops with the falling level of the liquid to the level of opening c in extension arm d, seals this opening, and remains in this position for as long as the sewer is under vacuum. The evacuation of each sump causes a fluctuation of the manometer needle. These vibrations are counted by the laborer and checked with a number written on the pedal in the sump, the number corresponding with the number of sumps on the street sewer. In this manner, in the space of several minutes the worker can connect and disconnect, in rotation, each of the street sewers with the collector and continue to the next sub-station.

The solids deposited in the first chamber of the tank at the central plant are withdrawn in a similar manner to elevated basins, and then pass on to units provided for their recovery and treatment.

Advantages of System

The process of emptying the sewers under vacuum is the major difference between the operation of normal sewerage systems and that developed by Gandillon. Normal sewer systems are laid at certain minimum slopes to provide sufficient velocity for self cleansing to prevent deposition of suspended solids. However, as a result of fluctuating flows, deposition does occur and they must be cleansed from time to time, either by mechanical means or by flushing.

All small-sized sewers are generally cleansed by flushing with water from special flush tanks. Because of the relatively small accumulation of water (usually only 3 ft. in depth), the velocity of water discharging into the sewer is quickly reduced, and the flushing effect extends only a short distance (about 490 to 660 ft.). The effective work accomplished by the flushing water is not very great. Gandillon estimates that the work performed by 35.3 cu. ft. of water, which flows into a 16-in. diameter sewer at an initial discharge of 20 cu. ft. per sec., amounts to only 4,000 ft.-lb. He considers the use of water for flushing sewers to be wasteful, as not only is it potable but it is also distributed at a pressure of 4 to 6 atmospheres, from which only about 2 in., on the average, is recovered.

Instead of water, which in some areas is obtained or processed with great difficulty, Gandillon uses air, which is available everywhere and in unlimited amounts. Moreover, air exerts a pressure of 14.7 lb. on each square inch of area, or it is equal to the pressure exerted by a 34-ft. column of water.

According to Gandillon's computations, based on experimental data, the quick connection to the atmosphere of a 16-in. diameter sewer containing a vacuum equal to 1.64 ft. of mercury (about 0.34 atm. absolute) will cause air to rush into the sewer at a velocity of 616 ft. per sec. Attention must be called to the fact that the most destructive cyclones, which destroy towns and forests, have a velocity of less than half of the above figure.

Through special ports provided for observation purposes it was possible to note what takes place in sewers when they are opened to the atmosphere. Street sumps having a volume of 35.3 cu. ft. are emptied in a fraction of a second. All material passes the ports at high velocity and flows to the reservoir at the pumping station.

The usual practice after cleansing the sewer system under a vacuum is

to permit atmospheric air to enter the main collectors directly. During this flushing it was necessary to hold tightly to one's hat, even when standing at a distance of 10 ft. from the valve, to prevent the suction from taking it to the treatment plant. Large rags and newspapers thrown into the air at a distance of approximately 6.5 ft. from the valves were instantly drawn into the main collector.

It is not surprising that not much attention is paid to the sewer use statutes and that anything that will pass through the openings in the sink drain is put into the sewer. Large tin cans are common and there have been found in the sludge even such items as a silica stone about 4 in. in diameter, various pieces of iron, and a piece of lead weighing 26.4 lb.!

The force of the current is so great that heavy objects travel along the center of the sewer and do not touch the sides. If the energy of air is taken into consideration, everything stated previously is understandable. According to Gandillon's computations, during the flushing operation a minimum of 66 lb. of air is used. This air liberates 371,000 ft.-lb. of energy, or 100 times more than 35.3 cu. ft. of water used in the normal manner for flushing sewers.

To maintain this effective cleansing, two 17-hp. vacuum pumps are put into operation for a period of 2 hr. each day. Three laborers are also required: one machinist, and two laborers to operate the valves at the sub-stations.

Newer Adaptations

In the latest sewer system of this type (Fort-de-France, Martinique), special inlets were provided below street level so that street cleaners may discharge sweepings and other wastes collected from the streets. A pedal is pressed at the inlet and the contents are drawn into the sewer and to the basins at the treatment plant.

Gandillon believes that, before long, communities having similar sewerage systems will be able to clean street surfaces with equipment similar to home vacuum cleaners, which would be connected by hoses to special fittings attached to the street sewers.

Sewage Treatment Plant

Wastes flowing to the central plant during the period of gravitational operation are pumped to the treatment plant. In St. George the wastes are pumped to an equalizing tank, which also serves as a pre-sedimentation chamber, then flow by gravity to a primary sedimentation basin, trickling filters, and final settling tanks, and finally are discharged into the stream (see Figure 1).

During the period when the sewers are being cleansed, much solid material flows to the two reservoirs at the pumping station. The larger solids are retained in the first chamber of each tank. They are then pumped to the two elevated tanks, from which they flow into a special settling basin-decanter. The liquid fraction is pumped to the treatment plant, and the solids are digested thermophilically.

Digestion Processes

It must be noted that the French have made notable advances in the field of garbage (waste) fermentation.

The Beccari process, which is used in many Italian (and in some American) communities, takes place in a closed chamber under anaerobic conditions. The disadvantages are: (1) the time required (approximately 60 days); (2) the need of a large number of cells (for example, Florence, with a population of 200,000, would require 204 cells); and (3) the incomplete utilization of the volume of the cell, which at the start is full, but which after several days and for the remainder of the process is only about half full as a result of compaction of the fermenting mass.

Anger, who did research work during the years 1927–1930 relative to

the problem of treating the wastes at St. George, found that the addition of air to the cell during the fermentation process greatly accelerated the digestion. He found, too, that the temperature either remained constant or increased during this process. In Anger's experiments he used 4 cells, each with a volume of 705 cu. ft. and elevated about 10 ft. above the ground to facilitate removal of the contents. These cells were filled with the solid contents from the "decanter," to which was added the fresh raw sludge from the settling tanks. The temperature then rose to 70° C., and the process was continued for 20 days. After fermentation, the wastes were sorted and the residue sold to farmers for 40 to 50 francs per ton (1934 franc rate).

A new project, approved by the municipal authorities of St. George in December 1931, provided for the construction of 40 cells, each with a capacity of 705 cu. ft. Half of the cells were put in use, but the others were reserved as auxiliary units to be utilized as the municipality grows.

Other Systems

In connection with this, it is desirable to call attention to other fermentation systems utilizing this process. In Geneva, a plant was built incorporating the Biaggiano-Pico system, which, instead of cells, employs a hermetically sealed tower having a capacity approaching 56,500 cu. ft. The tower is filled from above and emptied from below. Air is introduced from below at a pressure of 7 atm. Fermentation time is longer (35 days), which may be explained by the fact that the mass of fermenting material is excessive.

The experimental studies of Joan Bordas in 1931 led to the construction of a fermentation silo for continuous operation. The silo is slightly cone-shaped and its walls are insulated with a layer of air. Air is introduced along the length of the walls and through a central pipe, which is surrounded on the outside by a metal spiral for the addition of water to moisten the fermenting mass. Inside, the silo is divided by means of a grate made up of two movable sections. The upper portion of the silo includes a platform, a feed inlet, and a small tower for absorption of ammonia gas by superphosphate.

In the lower section of the silo there are two openings for the discharge of liquid wastes and water, and two openings for the removal of the solid material. The first feed of wastes, which amounts to 705 cu. ft., is loaded onto the grates. In addition, 22 lb. of urine, or steep liquor, and some horse manure are added. This material is interspersed between layers of wastes. After loading, the wastes are moistened with 53 gal. of slightly warmed water or manure liquor.

After 12 to 15 days the grates are lowered and the entire contents of the silo fall to the bottom, where they now occupy a volume of 420 cu. ft., and an additional 705 cu. ft. of wastes is added to the lower layer. The grates are then lowered to a horizontal position and the loading cycle repeated.

In this manner, almost the entire volume of the silo is utilized in the process. After several operations the process may be reduced to 20 days. Through use of the space remaining after compaction of the wastes, a silo with a capacity of 1,600 cu. ft. can treat 2,115 cu. ft. of wastes. As a result of action of the urine and horse manure, the temperature rises to 80° C. after the first day and thereafter remains at 65° C. The urine and the manure thus are completely utilized. Superphosphate is added to the latter from the absorption tower.

It should be noted that aerobic fermentation, which was begun in France for treating wastes and a mixture of wastes and sewage, found further development in the United States, where it was utilized for treating sewage wastes alone. Studies by Rudolfs and

Heukelekian (1) show that the aerobic fermentation of sludge gives better results than does normal fermentation under anaerobic conditions. Anaerobically digested sludge followed by aerobic digestion indicated removals in organic matter of 42.7 per cent, organic nitrogen 52.6 per cent, grease 61.4 per cent, and B.O.D. 93 per cent, whereas anaerobic sludge subjected to anaerobic digestion showed no change.

Public Health Connotations

Szniolis believes that the Gandillon system leaves little to be desired, because of the following reasons:

1. Immediate and direct removal of all organic wastes and sewage from households, stores, and restaurants, as well as from the entire area of the city, results in a clean city and reduces the number of flies, mice, and rats.

2. Removal of wastes by means of a tight system of pipes eliminates the hazard of ground and ground-water pollution resulting from leakage of sewage into the ground.

3. Daily pneumatic cleansing of the sewers keeps out rats.

4. This method of cleansing sewers enables workmen to remain outside. Even those at the treatment plant need not come in close contact with the sewage. Moreover, the sorting of wastes (garbage and refuse) occurs only after the fermentation process.

Economic Phases

The cost of the sewerage system is dependent on many factors. Above all else, local conditions govern; that is, topography, ground conditions, ground-water level, population, type of construction, length of streets, distance to and type of plant, cost of materials and labor, etc. Because of this, cost data relative to this system, as compared with any other, can only be considered on the basis of a few variables for the same city.

TABLE I.—Comparative Cost Data for Sewerage Systems in St. George and Two Polish Cities

	Ostrow Wielkopolski	Gniesno	St. George
Type of system	Combined	{Combined / Separate}	Separate
Type of treatment	Irrig. fields	Imhoff tks. and tr. filt.	Sedim. and tr. filt.
Population, total	22,000	27,000	20,000
Population, connected	20,000	24,750	18,000
Houses connected	458	702	1,270
Storm sewer (ft.)	14,750	3,280	21,900
Sanitary sewer (ft.)	19,670	———	44,000
Combined sewer (ft.)	———	65,600	———
Total sewer (ft.)	34,420	68,880	65,900
Depth (ft.)	8.2–12.3	9.8–16.4	(Max.) 11.3
Material, storm	Concrete	Concrete	Concrete
Material, sanitary	Tile	Tile	Cast iron
Construction cost, total	$253,500	$579,000	$523,500
Construction cost, per ft.	$7.36	$8.24	$7.96
Construction cost, per cap.	$11.50	$21.43	$26.15
Operation cost, annual	$7,900	$21,550	$11,460[1]
Operation cost, per ft.	$0.23	$0.32	$0.18
Operation cost, per cap.	$0.36	$0.80	$0.57
Flushing water (m.g./yr.)	14.5	2.64	———
Maint. personnel	15	27	6[2]
Sewage flow[3] (m.g.d.)	0.383	0.66	0.344

[1] $6,185 for staff, $4,065 for power, and $1,210 for lubrication, heating, etc.
[2] Includes three workers who maintain the storm sewers.
[3] Not including storm flows.

Comparative cost data for St. George and for two Polish towns of similar population are represented in Table I. From the data will be seen that neither the cost of construction nor that of operation is any greater than that for other sewerage systems. Actually, it is cheaper when the added advantage of the reduced cost of the removal of garbage and refuse is considered.

With respect to the cost, consideration must be given to the fact that (1) in St. George the homes are small and relatively scattered (total of 1,270 connections), (2) household connections were made at the expense of the municipality, and (3) difficulties arose in construction because of ground-water conditions. Further, the data given include the cost of experimentation and of the major changes in sewerage facilities instituted over a period of 20 years.

Conclusions

Szniolis is of the opinion that the Gandillon sewerage system may have excellent prospects in Poland, as it provides a simple and inexpensive means of sewering level and high ground-water areas, of which there are a great number in Poland. The entire sewerage system may be placed close to the ground surface. For sewering the house below street level it is not necessary for the sewer system to run below the house connection, as it does in the normal type of sewer system. In this instance it is only necessary to provide a tank large enough to hold the day's flow. This tank is connected to the street sewer. When the sewers are evacuated, the material from this tank is drawn into the street sewer in a manner similar to that employed in removing the contents of the street sumps.

With a slight change it would be possible to remove the wastes and sewage from a settlement in which the homes are served by septic tanks. This would have particular application to the sanatoria, or health resorts, in Poland.

As further confirmation of the value of the Gandillon sewerage system, it should be noted that several others have developed similar systems and are building suitable appurtenances in smaller settlements. These systems are neither cheaper, nor simpler; however, they have many followers. For example, the L. Garchey system includes a sump-settling basin that serves each house. All wastes discharge into this unit and a portion flows out by gravity to normal sewers laid at a flat slope. The solid fractions are removed periodically, by vacuum, into another sewer system made of cast-iron pipe. The entire system is, of course, very expensive, but even at that there are three cities (Cite-Jardins de Drancy, Malabry, and de Plessis-Robinson) that are utilizing this system.

Some of the schemes have utilized kitchen sinks for the removal of all household wastes and have connected them to the sewer system. For this purpose, the kitchen sinks are located in the basement and are provided with screens, upon which all solids and wastes are retained, while the screened liquors pass on to the sewers. The material collected on the screens is air dried and burned in incinerators, which are adjacent to the sinks in the basement. The Garchey sinks have a larger capacity, are not equipped with a siphon, and permit the discharge of any material that will pass the opening. These units have found wide use. More than 10,000 have been installed in France by the Garchey firm, with about 2,000 in use today in Paris alone.

Reference

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PURIFICATION OF SEWAGE IN LAGOONS

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Purification of sewage and industrial wastes by holding in ponds or lagoons has been practiced in America for several years. The treatment of sewage by this method has been described by Caldwell (1), Giesecke and Zeller (2), and Blackstone (3). Industrial wastes, particularly from canneries, have also been shown to be capable of purification in this way by Sanborn (4) and others. The whole subject of treatment by lagoons or oxidation ponds has been reviewed by an American Public Health Association committee (5). In Australia, lagoons are used at times in treating sewage from small towns, their main application being for the final treatment of effluents otherwise considered unsuitable for discharge after treatment by primary and secondary processes.

Although their use is therefore not uncommon, there is no general recognition of lagoons as an efficient method of sewage purification; in general, they have been considered a primitive form of treatment. There has been little scientific investigation of the fundamental processes involved and the factors affecting the efficiency of such treatment. In some cases, lagoons have been discredited because overloading, due to lack of intelligent appreciation of the principles involved, has given rise to septic conditions and unsatisfactory effluents.

Melbourne Studies

The greater part of the sewage of Melbourne—population 1,250,000; dry-weather flow, 62 m.g.d. (Imp.)*, or 74 m.g.d. (U. S.)—is purified by land treatment at a 25,000-acre farm at Werribee, 20 miles from the city. The methods of purification adopted have been described elsewhere by Borrie (6) and McIntosh (7). Briefly, they are by rotational irrigation of pastures with raw sewage in the summer and the continuous surface application of settled sewage to grassed areas in the winter. In the autumn and spring, transition between these two methods is effected over a period of several weeks. Weather conditions during these transitional periods introduce certain operational difficulties. The use of lagoons appeared to offer an alternative form of treatment that not only would facilitate operational procedure during these periods, but also would be useful in the treatment of peak night flows (because of the distance from the city, the daily peak flow reaches the farm between 10 P.M. and 6 A.M.) and excess wet-weather flows resulting from infiltration into the sewerage system.

For these reasons, and because there are areas of land on the farm which are not suitable for land treatment, but which could be converted to lagoons, studies were commenced in 1940 at the direction of E. F. Borrie, chief engineer of sewerage, to determine the purifying capacity of lagoons and the factors affecting their performance under Australian condi-

* All flows in this paper are expressed in terms of Imperial gallons unless otherwise specified.

tions. The results of these studies are described in this paper.

It was obvious from the literature and was soon apparent from the experiments that, apart from the presence of algal growths, a satisfactory effluent could be produced by lagoon treatment. The studies were directed, therefore, towards the determination of the exact capacity for purification possessed by lagoons when operated in the following ways:

1. For the continuous purification of the dry-weather flow of raw sewage.
2. For the purification of excessive storm flows admitted to the lagoons intermittently as they occur.
3. For the continuous final treatment of effluents either from treatment plants or from the land treatment of sewage.

The factors affecting each of these methods of operation is discussed in turn.

Effluent Standard

Before describing the experimental work it is necessary to consider the standard of final effluent desired from lagoon treatment. In Australia there is no legal standard set up for sewage effluents discharged to rivers, streams, or the open sea, although general recognition is given to the British Royal Commission standard requiring a B.O.D. not greater than 20 p.p.m. and suspended solids not greater than 30 p.p.m. In general, effluents which do not comply with it would be considered unsatisfactory.

Strict observance of this standard with lagoon effluents is rendered difficult because of the presence of algae. It has been observed by Caldwell (1) in California, and has also been found under Australian conditions, that sewage lagoon effluents frequently have a green to yellow turbidity due to the development of minute free-swimming green algae in the lagoon. These exert an oxygen demand when incubated in the B.O.D. test. As a result, lagoon effluents fluctuate widely in B.O.D. and suspended solids, due predominantly to variation in the numbers of algae present rather than to the amount of residual pollution. Such effluents frequently exceed the above standard for both B.O.D. and suspended solids, even when complete stabilization of the original organic pollution is achieved. When the green algal material is removed from such effluents by filtering through filter paper, the B.O.D. is much reduced, usually below 10 p.p.m. The desirability of discharging such effluents is discussed subsequently, but at this point it should be stated that for the purposes of these experiments a lagoon effluent was considered satisfactory for discharge provided the B.O.D., after removal of the algae by filtration, was less than 20 p.p.m.

The correctness of this contention is open to question, particularly if the effluent should contain suspended sludge or other particles of organic matter at times when the lagoon contents are disturbed by wind action. However, apart from this possible objection, it is reasonable to believe that with stabilized lagoon effluents, suspended solids in the original sewage have already been settled, dissolved, or digested, and that the B.O.D. of the sample is associated only with the algal material and the dissolved organic matter remaining from the original sewage pollution. In assessing the performance of the lagoons in these studies, the filtered B.O.D. has proved a much more useful characteristic than the B.O.D. of the unfiltered effluent.

Assessment of Purifying Capacity

To arrive at the required dimensions of a lagoon for the complete treatment of any particular sewage flow, it is necessary to be able to define the purifying capacity of lagoons in some way. Experimental evidence is advanced

herein to show that the most satisfactory definition of purifying capacity is in terms of pounds of B.O.D. removed per acre per day; in the discussion of results, purifying capacity is defined in this way. On this basis, lagoon dimensions to purify a given flow are stated as a surface area based on the volume and B.O.D. of the sewage to be treated.

Not only the purifying capacity, but also the actual purification effected under any set of operating conditions, may be expressed in the same way, and may be calculated from the formula

$$\text{B.O.D. removal (lb./acre/day)} = \frac{B_1F_1 - B_2F_2}{A(10^6)} \quad (1)$$

in which B_1 is the B.O.D. of the influent, in p.p.m.; B_2 is the B.O.D. of the filtered effluent, in p.p.m.; F_1 is the inflow, in g.p.d. (Imp.); F_2 is the outflow, in g.p.d. (Imp.); and A is the area of the lagoon, in acres. It is necessary to determine the rate of both inflow and outflow to allow for evaporation and percolation losses. The B.O.D. of the filtered effluent is used in the equation in preference to the corresponding value of the unfiltered effluent for the reasons previously given.

Nature of Lagoon Processes

The literature, as well as present practice in Australia and America, suggests that the only form of lagoon treatment is by passage of sewage, usually after sedimentation, through a pond in which essentially aerobic conditions are established, and in which dissolved oxygen at times may reach supersaturated values through

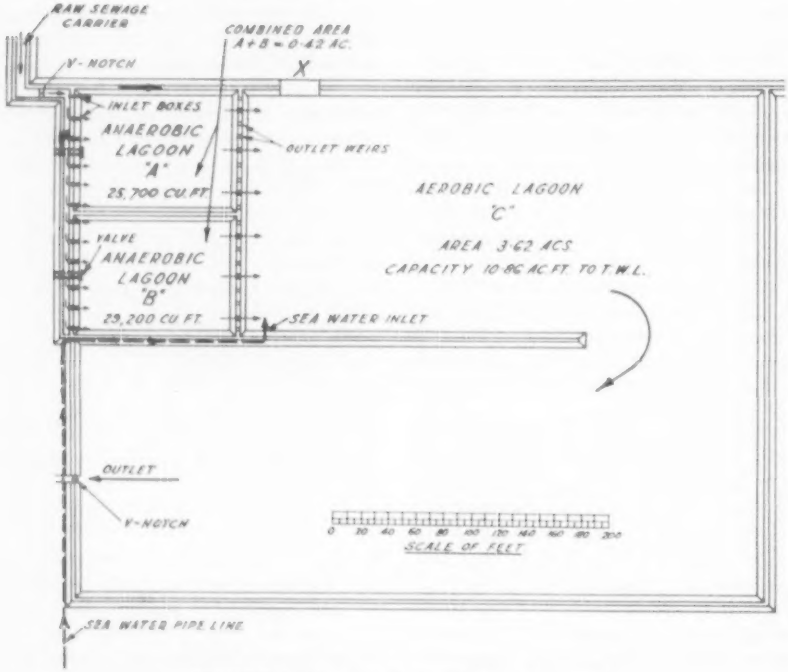

FIGURE 1.—Layout of experimental lagoons.

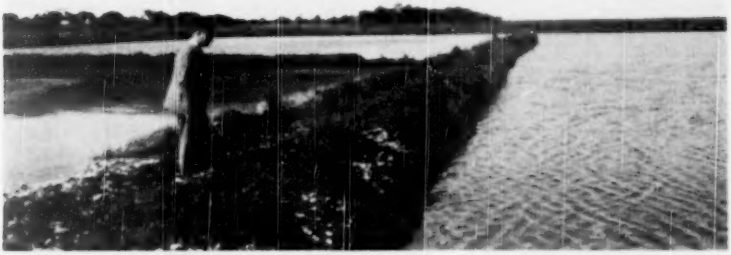

FIGURE 2.—Experimental lagoons, showing part of anaerobic lagoon B in left foreground and aerobic lagoon in background and right foreground.

algal activity. In addition to the examination of the performance of such lagoons, it has been found in the course of the present studies that substantial purification of raw sewage can be obtained in lagoons where conditions are deliberately kept anaerobic. Factors affecting the performance of such lagoons have also been examined. To differentiate the two forms of lagoon they are referred to as aerobic and anaerobic lagoons, respectively.

Experimental Lagoon Layout

The lagoons constructed for the experiments with continuous treatment of sewage are shown in Figures 1 and 2. The two anaerobic lagoons, A and B, were shallow bays 8,600 sq. yd. and 9,700 sq. yd. in area, respectively, constructed with earth banks and operated with a water depth of 3 ft. These lagoons served as sedimentation units, as well as purifying lagoons, and facilities were provided for desludging them manually. The detention time in these units was 30 to 60 hr., depending on the rate of flow. The aerobic lagoon, C, had an area of 3.62 acres and was similarly constructed with earth banks. By manipulation of the outlet weir it could be operated with a water depth from 0 to 3 ft.

The raw sewage inflow was measured over a V-notch weir and entered the anaerobic lagoons through multiple inlets operated to give the same detention time in each unit. Effluent from the anaerobic lagoons flowed into the aerobic lagoon through outlet boxes provided with baffles to prevent floating scum from entering the latter. The effluent from the aerobic lagoon was measured over a V-notch weir.

In all experiments with continuous operation, the flow was maintained constant over 24 hr. of the day and over the whole period of the particular experiment. Grab samples of raw sewage and the effluent from the three lagoons were taken twice weekly over each period of operation. The raw sewage sample was taken at a time of the day when the B.O.D. was comparable with that of a 24-hr. composite. Because of the considerable detention time in each lagoon, there was little hourly variation in the characteristics of the effluents, so that grab samples at these points were also sufficient.

Continuous Aerobic Treatment

With the layout shown in Figure 1, the sewage treated by the aerobic lagoon was the effluent from the anaerobic lagoons, in which the raw sewage had already been settled and some B.O.D. reduction had occurred. The nature of the influent to this lagoon was influenced, therefore, by changes

TABLE I.—Performance of Aerobic Lagoon with Increasing Flow

Item	Period		
	July 7 to Oct. 13, 1941	Sept. 24 to Dec. 24, 1942	May 28 to Sept. 17, 1942
Flow, influent (g.p.d.)[1]	120,000	140,000	140,000
Flow, effluent (g.p.d.)[1]	98,000	120,000	128,000
Lagoon area (acres)	3.62	3.62	3.62
Lagoon depth (ft.)	3.0	3.0	3.0
B.O.D., influent (p.p.m.)	154	172	272
B.O.D., effluent (p.p.m.)	49.5	44.3	83
B.O.D., filtered effl. (p.p.m.)	14.6	14.8	65
Loading (g.p.d./acre)[1]	33,100	38,700	38,700
Loading (lb. B.O.D./acre/day)	51.7	66.5	105
Performance (lb. B.O.D./acre/day)[2]	47.1	61.6	82.2

[1] Imperial gallons.
[2] Removal to filtered effluent.

in the degree of purification occurring in the anaerobic lagoon.

Nature of Sewage Treated

The sewage treated was the normal dry-weather flow from the Melbourne sewerage system. A full analysis of a typical 24-hr. composite shows 530 p.p.m. B.O.D., 436 p.p.m. suspended solids, 32 p.p.m. ammonia nitrogen, 41.7 p.p.m. organic nitrogen, 530 p.p.m. chlorides, no nitrate or nitrite nitrogen, no dissolved oxygen, and pH 7.0.

Purifying Capacity

The purifying capacity was determined by increasing the flow of sewage through the lagoons until the B.O.D. of the filtered effluent of the aerobic lagoon exceeded 20 p.p.m. The experiment was carried out with a lagoon depth of 3 ft. and each rate of flow was applied for a period of 3 to 6 months.

The relevant data for three operations are shown in Table I, in which the purifying capacity is calculated according to Eq. 1. When the flow was 140,000 g.p.d. and the influent B.O.D. 172 p.p.m., the filtered effluent B.O.D. was less than 20 p.p.m. With flows less than 140,000 g.p.d. and similar influent B.O.D., or with a flow of 140,000 g.p.d. and lower influent B.O.D., the filtered effluent B.O.D. remained below 20 p.p.m. When the flow was increased beyond 140,000 g.p.d. with the influent B.O.D. maintained at approximately 172 p.p.m., and also when the influent B.O.D. exceeded this value and the flow was maintained at 140,000 g.p.d., the B.O.D. of the filtered lagoon effluent was substantially greater than 20 p.p.m. It must be concluded, therefore, that conditions set out in Table

TABLE II.—Performance of Aerobic Lagoon with Increasing B.O.D. Loading

Flow, influent (g.p.d.)	100,000	120,000	140,000	140,000	250,000
Flow, effluent (g.p.d.)	82,000	98,000	120,000	128,000	233,000
B.O.D., influent (p.p.m.)	235	154	172	272	289
B.O.D., effluent[1] (p.p.m.)	11.0	14.6	14.8	65	226
B.O.D. loading (lb./acre/day)	65	51.7	66.5	105	202
B.O.D. removal (lb./acre/day)	62.4	47.1	61.6	82.2	54.1
B.O.D. reduction (%)	95.4	89.6	92.0	76.2	31.2

[1] Filtered.

I with a flow of 140,000 g.p.d. and influent B.O.D. of 172 p.p.m. closely approximate the maximum loading the lagoon can treat to a satisfactory degree.

The B.O.D. load applied to the lagoon under these conditions was 66.5 lb. per acre per day; the removal was 61.6 lb. per acre per day, based on the B.O.D. of the filtered effluent. The purifying capacity of the lagoon to treat sewage on a continuous flow basis was, therefore, about 60 lb. B.O.D. removed per acre per day. It is of interest that the value of 50 lb. per acre per day calculated on the unfiltered effluent B.O.D. has frequently been quoted by American authorities as the purifying capacity under American conditions, a value of the same order as that found in these experiments.

Effect of B.O.D. Loading

Table II gives the performance of the lagoon with increasing B.O.D. load. The data show that with B.O.D. loadings up to 66 lb. per acre per day substantially complete removal is achieved and effluents with a filtered B.O.D. less than 20 p.p.m. may be expected. When the B.O.D. load is increased to 105 lb. per acre per day, increased removal is obtained, but the B.O.D. of the filtered effluent is no longer less than 20 p.p.m. With further increase to 202 lb. per acre per day, the B.O.D. of the filtered effluent increases further and the B.O.D. removal deteriorates. With increase in loading from 0 to 67 lb. B.O.D. per acre per day, the percentage removal remains between 90 and 100; with increase beyond 67 lb. per acre per day, the percentage reduction diminishes according to a straight-line relationship.

The data also show that there is a maximum value for B.O.D. removal, which is 80 to 85 lb. per acre per day. This occurs at a B.O.D. loading of 105 to 120 lb. per acre per day. Up to this loading, increased removal is achieved; beyond it, there is a reduction in performance. At the loading to give the maximum performance the B.O.D. of the filtered effluent is not satisfactory, being 65 p.p.m., or considerably above the acceptable standard of 20 p.p.m. It is not practicable, therefore, to operate aerobic lagoons to utilize their maximum purifying capacity and obtain a satisfactory effluent. The maximum loading to give a satisfactory effluent is 70 lb. per acre per day, which may be taken as the maximum removal of B.O.D. which is possible by aerobic lagoon treatment to produce an effluent with filtered B.O.D. less than 20 p.p.m. under the

TABLE III.—Analyses of Sewage at Various Stages of Lagoon Treatment

Component	Raw Sewage	Lagoon[1] Influent	Lagoon Effluent	Lagoon Effluent (Filtered)
B.O.D. (p.p.m.)	530	160	51.3	6.6
Susp. solids (p.p.m.)	436	94	194	Nil
Ammonia N (p.p.m.)	32	56	18	16
Organic N (p.p.m.)	41.7	11.6	24.2	6.3
Nitrite N (p.p.m.)	Nil	Nil	Trace	Trace
Nitrate N (p.p.m.)	Nil	Nil	Nil	Nil
Chlorides (p.p.m.)	530	555	675	675
pH	7.0	7.5	8.2	8.2
Dissolved oxygen (p.p.m.)	Nil	Nil	2–30	—
E. coli (orgs./ml.)	800,000	250,000	350	—

[1] Effluent of anaerobic lagoons.

conditions existing at Werribee. As will be seen later, it is largely independent of any other variables.

Chemical and Bacteriological Changes

Analyses of typical samples of raw sewage, and anaerobic lagoon and aerobic lagoon effluents, unfiltered and filtered, are given in Table III. In passing through the aerobic lagoon there was an increase in suspended solids from 94 to 194 p.p.m., due to algal growth; a drop in B.O.D. from 160 to 51.3 p.p.m.; ammonia nitrogen decreased and organic nitrogen increased, due to a synthesis of organic algal material. Filtration of the lagoon effluent reduced the B.O.D. from 51.3 to 6.6 p.p.m. and the organic nitrogen content from 24.2 to 6.3 p.p.m., both reductions being due to the removal of the algal matter.

A reduction of coliform organisms similar to that remarked on by Caldwell (1) was also found, the count falling from 800,000 per ml. in the raw sewage and 250,000 per ml. in the anaerobic lagoon effluent to 350 per ml. in the aerobic lagoon effluent.

Effect of Depth

To determine the effect of depth on purifying capacity, the lagoon was operated at a constant flow of 140,000 g.p.d., first with a water depth of 3 ft., and then 18 in. Both operations were carried out for 3 months and samples were taken as for the experiments on purifying capacity. The results, averaged over each operation, are given in Table IV.

TABLE IV.—Influence of Lagoon Depth on Performance of Aerobic Lagoons

Item	Period	
	Sept. 24 to Dec. 24, 1942	Jan. 7 to Apr. 30, 1943
Flow, influent (g.p.d.)	140,000	140,000
Flow, effluent (g.p.d.)	122,900	123,300
Lagoon area (acres)	3.62	3.62
Lagoon depth (ft.)	3.0	1.5
Lagoon temp., av. (° F.)	64	64
B.O.D., influent (p.p.m.)	171	148
B.O.D., effluent (p.p.m.)	48	34.4
B.O.D., filt. effl. (p.p.m.)	15.2	16.1
Susp. sol., influent (p.p.m.)	115	100
Susp. sol., effluent (p.p.m.)	84	53
B.O.D. removal (lb./acre/day)	61.0	51.8
Detention (days)	21.4	10.7

The B.O.D. of the filtered effluent was almost identical in both cases, despite the depth in the first test being double that in the second. Although the purifying capacity with a 3-ft. depth was slightly greater than with an 18-in. depth, this difference is probably due to the higher influent B.O.D. in the first case. It was shown previously that, within a certain range, the greater the B.O.D. loading the greater the performance to be expected. Although the performance at depths less than 18 in. and greater than 3 ft. was not examined, it is reasonable to conclude that over the range of depth likely to be used in lagoons, the depth does not appreciably affect the purifying capacity.

The fact that purifying capacity is independent of depth means that the same daily flow of sewage can be purified to the same extent per unit area of lagoon, irrespective of its depth.

As the detention time was 10.7 days in one case and 21.4 days in the other, the detention time also bears no relationship to the capacity of the lagoon for purification. This supports the statement made earlier that it is preferable to express the purifying capacity of lagoons as pounds of B.O.D. removed per acre per day, rather than as pounds of B.O.D. removed per acre-ft. per day or in terms of detention time. If this conclusion is of general application, passage of a thin sheet of sewage over land should be just as effective as lagoons of the depth examined. No experiments were carried out in this range, but it is of interest that B.O.D. removal by the process of continuous surface application of sewage to grassed areas is of the order of 100 lb. B.O.D. per acre per day, which is somewhat greater than the values found with the present lagoon.

TABLE V.—Effect of Seasonal Conditions on Performance of Aerobic Lagoons

Item	Period	
	Winter May 28 to Sept. 17, 1942	Summer Sept. 24 to Dec. 24, 1942
Flow, raw sewage (g.p.d.)	140,000	140,000
Flow, effluent (g.p.d.)	127,600	122,900
Lagoon area (acres)	3.62	3.62
Lagoon depth (ft.)	3.0	3.0
Lagoon temp., av. (° F.)	52° F.	64° F.
B.O.D., raw sewage (p.p.m.)	388	184
B.O.D., influent[1] (p.p.m.)	272	172
B.O.D., effluent (p.p.m.)	83	44.3
B.O.D., filt. effl. (p.p.m.)	65	14.8
Susp. sol., raw sewage (p.p.m.)	220	366
Susp. sol., influent[1] (p.p.m.)	97.5	115
Susp. sol., effluent (p.p.m.)	56	85
B.O.D. removal (lb./acre/day)	82.2	61.6
B.O.D. reduction (%)	76.1	91.2

[1] Anaerobic lagoon effluent.

Seasonal Effect

To determine the influence of temperature and other seasonal factors, the lagoon was operated with the same flow under winter and summer conditions. The results are given in Table V.

The purifying capacity of 82.2 lb. per acre per day in winter was greater than the summer value of 61.6. This indicates that temperature, algal population, and other factors which might be expected to favor better summer performance, have an insignificant effect on purification capacity. This suggests that some other factor limits the biological activity in summer, probably the rate of oxygen absorption at the water surface. In winter, with lower temperatures, the solubility of oxygen is greater and consequently the rate of solution into water containing less than the saturation value of dissolved oxygen would also be greater. This probably explains why the performance is as great or greater in winter than in summer. The reason for the better results in winter is also to some extent associated with the higher B.O.D. value of both influent and filtered effluent for that operation. It is established in trickling filter studies that it is much easier to reduce the B.O.D. by 100 p.p.m. from 350 to 250 p.p.m. than from 150 to 50 p.p.m. The same probably applies in lagoon treatment, with the result that performance over the B.O.D. range of the winter operation would be expected to be better than over the range of the summer operation. Thus, it is probable that had the influent B.O.D. been the same in both cases, the purifying capacity would be similar in summer and winter.

Despite the constant flow during both periods, and the higher purifying capacity and lower raw sewage B.O.D. in winter, the B.O.D. of both unfiltered and filtered effluents was much higher in winter than in summer. This suggests that the over-all performance of anaerobic lagoons plus aerobic lagoons treatment is less in winter than in summer.

Although the raw sewage B.O.D. was lower in winter, the B.O.D. of the anaerobic lagoon effluent entering the aerobic lagoon was higher, thus imposing a much higher B.O.D. load on the latter lagoon in this period. This is reflected in and accounts for the higher B.O.D. of the winter effluents. The reason for the smaller B.O.D. reduction through the anaerobic lagoon, and consequent higher B.O.D. of the effluent from this unit in winter, is discussed in connection with the performance of anaerobic lagoons.

Continuous Anaerobic Treatment

In the experimental lagoon setup used (Figure 1), the raw sewage passed continuously through the two anaerobic lagoons before entering the aerobic lagoon. In the two anaerobic lagoons the detention time was 2½ days and the sludge deposited by sedimentation was only removed at infrequent intervals (3 to 4 years).

Purifying Capacity

Although one function of the anaerobic lagoons was the removal of

suspended solids before aerobic lagoon treatment, Table III shows that B.O.D. removal was also considerable. The B.O.D. reduction from 530 to 160 p.p.m. (70 per cent) is very much greater than that to be expected from the simple removal of the B.O.D. associated with the solids settled out. When the performance of the anaerobic lagoon is calculated from the values in Table III in the same way as for the aerobic lagoon, it is found that the purifying capacity is 1,230 lb. per acre per day, compared with 65 lb. per acre per day for the aerobic lagoon process. This suggests that the anaerobic lagoon is a much more efficient purification unit than the aerobic lagoon.

Effect of Deposited Sludge

One function of the anaerobic lagoons was the sedimentation of suspended solids. As the deposited sludge was only removed at intervals of several years and the detention time of the sewage in these lagoons was 2½ days, experiments were carried out to determine the part played by the deposited sludge in the very high B.O.D. removal observed. To do this, one lagoon, A, was completely desludged, whereas the sludge accumulated (16 in.) from two years of operation was allowed to remain in lagoon B.

Raw sewage was applied to both lagoons continuously at a rate such that the loading per unit area was the same for both units. Disregarding the presence of sludge in B, the detention time would be the same in both; however, because of the sludge, the detention time in B in fact would have been less than in A. The experiment was continued for nine months, samples of raw sewage and the effluents from the two lagoons being taken twice weekly. The results, averaged over four successive periods during the nine months (Table VI), show that at the commencement of the experiment, despite the shorter detention time, a much greater B.O.D. removal was obtained when the sewage passed through unit B (containing the accumulated sludge), the B.O.D. of the effluent being 98 p.p.m. lower than from A.

TABLE VI.—Influence of Sludge Layer on Performance of Anaerobic Lagoons

Period	B.O.D. (p.p.m.)		
	Raw Sewage	Effluent, Unit A	Effluent, Unit B
Apr. 9 to May 21	407	231	133
May 21 to Sept. 17	407	291	254
Sept. 17 to Dec. 3	484	205	138
Dec. 3 to Dec. 24	448	157	145

Table VI also shows that the difference in B.O.D. between the effluent from the two lagoons diminished as the experiment progressed and sludge built up in A. At the end of nine months there was a difference of only 12 p.p.m. in the B.O.D. of the two effluents.

The difference in B.O.D. reduction between the two lagoons at the beginning of the experiment can only be due to the presence of the sludge accumulated in B. This is confirmed by the relative improvement in the B.O.D. reduction through A as sludge was deposited in that lagoon also.

The high efficiency of the anaerobic lagoon in removing B.O.D. is dependent on the development of digestion

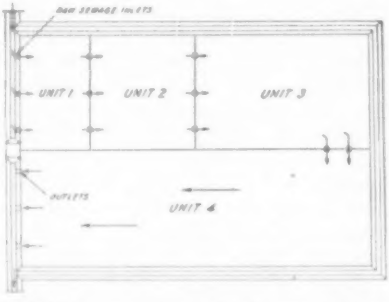

FIGURE 3.—Subdivision of lagoon A into four small anaerobic units in series.

TABLE VII.—Changes in Constitution with Increased Detention in Small Anaerobic Lagoon Units[1]

Sampling Point	Characteristic[2]	Period 1 (12/4/43–1/7/44)	2 (1/12/44–3/30/44)	3 (4/6/44–6/4/44)	4 (7/1/44–10/6/44)	5 (11/17/44–3/6/45)
All	Flow (g.p.d.)	16,000	16,000	16,000	16,000	16,000
	Temp. (°F.)	67.4	66.7	56.4	53.0	67.3
Raw sewage	B.O.D.	492	543	405	355	331
	Susp. sol.	470	637	433	366	195
Unit 1 effl.	B.O.D.	264	260	225	269	197
	Susp. sol.	115	117	104	84	104
Unit 2 effl.	B.O.D.	192	200	189	228	161
	Susp. sol.	77	60	70	69	65
Unit 3 effl.	B.O.D.	134	158	138	182	107
	Susp. sol.	90	126	66	50	90
Unit 4 effl.	B.O.D.	97	54.2	96	148	49.6
	Susp. sol.	78	91	72	54	77

[1] Averaged over each period as shown.
[2] In p.p.m. except as noted.

in the sludge layer. Organic matter is converted to methane and carbon dioxide under anaerobic conditions and the gassing of the sludge layer seeds the sewage flowing over it. With a detention time of 2½ days, substantial conversion of organic compounds to gaseous end products also occurs in the supernatant sewage and this is responsible for the high B.O.D. reductions that occur in the absence of dissolved oxygen.

TABLE VIII.—Effect of Detention on Performance in Small Anaerobic Lagoon Units

Unit No.	Det. Period (days)	B.O.D. Red. or Rem.[1]	Comparison[2]	Period Number[3] 1	2	3	4	5
1	1	Red.	R.S.	228	283	180	86	134
			Infl.	—	—	—	—	—
		Rem.	R.S.	1,862	2,309	1,469	702	1,093
			Infl.	—	—	—	—	—
2	1½	Red.	R.S.	300	343	216	127	170
			Infl.	72	60	36	41	36
		Rem.	R.S.	981	1,122	706	415	556
			Infl.	391	326	196	223	196
3	2½	Red.	R.S.	358	385	167	173	224
			Infl.	58	42	51	46	54
		Rem.	R.S.	583	628	435	282	365
			Infl.	190	137	167	150	177
4	5	Red.	R.S.	395	489	307	207	281
			Infl.	37	104	40	34	57
		Rem.	R.S.	324	401	252	170	230
			Infl.	60	169	65	55	93

[1] B.O.D. reduction in p.p.m., or removal in lb. per acre per day.
[2] Raw sewage to effluent from particular unit, or influent to effluent in particular unit.
[3] Dates and temperatures same as in Table VII.

Detention Time

To establish the relationship between purification capacity and detention time for the anaerobic lagoon process, lagoon A was subdivided into four units (Figure 3) so that the sewage would flow through them in series. The sludge previously accumulated in the lagoon was allowed to remain in each unit. The raw sewage flow and the area of the four units were adjusted to give a detention time of 1 day in the first unit, 1½ days in the second, 2½ days in the third, and 5 days in the fourth. This experiment was continued for 15 months, with the sewage flow maintained constant (16,000 g.p.d.) over the whole period and the raw sewage and the effluents from each unit being sampled twice weekly. The results, averaged over five periods during the experiment, are shown in Tables VII and VIII. In Table VII the average B.O.D. and suspended solids content of the raw sewage and effluents from each unit are shown for each period. In Table VIII, the purification effected by each unit is expressed as a reduction of B.O.D. in p.p.m. through that unit and also from the raw sewage to the effluent from the unit. The B.O.D. removal is also expressed as lb. B.O.D. removed per acre per day for each unit separately and additively with the previous unit or units.

The results in Table VII show that there is a progressive drop in B.O.D. as the sewage passes through the successive units. Thus, for the first period the raw sewage B.O.D. (470 p.p.m.) drops to 264 p.p.m. after passing through the first unit, to 192 p.p.m. after the second, to 134 p.p.m. after the third, and to 97 p.p.m. after the fourth.

When the results are calculated as B.O.D. removal per acre per day (Table VIII), it is seen that the B.O.D. removal diminishes with increasing detention time. Thus, for the first period, the removal in the first unit was at the rate of 1,862 lb. per acre per day, in the second unit 391, in the third 190, and in the fourth 60 lb. per acre per day. The B.O.D. removal in each of the first three units is much greater than that achieved by the aerobic lagoon (65 lb. per acre per day), but removal in the fourth unit, which increased the over-all detention from 5 to 10 days, was only of the same order.

It must be concluded, therefore, that a detention time up to 5 days in the anaerobic lagoon is desirable, but further detention is of no advantage compared with aerobic lagoon treatment.

Temperature

Table V shows that, in contrast to aerobic lagoons, there is a considerable difference in the B.O.D. reduction through the anaerobic lagoon in winter and summer. The reduction in winter was 116 p.p.m., compared with 312 p.p.m. in summer.

Owing to the wide variation in the B.O.D. of the raw sewage for the five periods shown in Tables VII and VIII, the effect of temperature on performance is not readily seen. However, the results for periods 4 and 5 with similar raw sewage B.O.D. show how the B.O.D. of the effluent from each unit was lower in period 5 when the temperature was higher. The over-all B.O.D. removal with 5-day detention varied from 628 lb. per acre per day for period 2 (av. temp. 66.7° F.) to 282 lb. per acre per day for period 4 (av. temp. 53° F.). These values are dependent on the B.O.D. of the sewage to be treated and the range of temperature of the lagoon contents.

More extensive tests have shown that under Melbourne conditions the B.O.D. removal with 5-day detention time for raw sewage with a B.O.D. of 550 p.p.m. may be taken as 600 lb. per acre per day in summer and 450 lb.

per acre per day in winter. To treat settled sewage with a B.O.D. of 350 to 400 p.p.m., the corresponding values are 400 lb. per acre per day in summer and 300 lb. per acre per day in winter.

The influence of temperature on B.O.D. removal is due to dependence on the sludge digestion process. The effect of temperature on sludge digestion is well established and it appears to influence B.O.D. removal in the same way.

Depth

Although no experiments were carried out to determine the effect of depth on the purifying capacity of anaerobic lagoons, it is probable that the purifying capacity of these units is dependent on the detention time or capacity of the lagoon, not on its surface area as in the case of aerobic lagoons.

Algal Development and Control

The presence of algal growth in purified lagoon effluents is of almost general occurrence. As a result, the effluent, instead of being sparkling clear, has an unattractive green to yellow turbidity, and as stated earlier the suspended solids content and B.O.D. as determined in the ordinary way are frequently much higher than would be considered satisfactory with effluents from filter or activated sludge treatment.

The desirability of discharging such effluents is therefore open to question. On the other hand, it has been stated by Caldwell (1) that the purifying capacity of lagoons is largely due to the photo-synthetic activity of algae, which normally develop in them. If this is so, algae are essential to the purification process and would have to be present for the lagoons to function efficiently. Experiments were carried out to establish some facts on these points.

Discharge of Effluents Containing Algae

A sample of lagoon effluent high in algal content was diluted with appropriate amounts of the ordinary laboratory B.O.D. dilution water, river water, and sea water. A 5-day B.O.D. test was performed according to standard procedure on one duplicate set of these dilutions, incubation being carried out in the B.O.D. cabinet in the dark. The duplicate set of dilutions were incubated for 5 days on the laboratory bench, where they were exposed to indirect sunlight. Dissolved oxygen determinations were made at the beginning and end of the period of incubation in each case.

The algae-containing lagoon sample incubated in the dark developed a B.O.D. of 37.8 p.p.m. with laboratory dilution water, 37.2 p.p.m. with river water, and 16.4 p.p.m. with sea water. The corresponding depletions of dissolved oxygen with a 1 in 20 dilution were 1.89 p.p.m., 1.86 p.p.m., and 0.82 p.p.m. The same dilutions incubated in daylight showed no depletion of dissolved oxygen and with the river and sea waters there was a substantial increase of 4.40 and 14.17 p.p.m., respectively.

Although it cannot be claimed that this experiment reproduces all possible conditions of discharge, the results do suggest that the laboratory determination of B.O.D. of lagoon effluents containing algae is unreal, and that in practice the dissolved oxygen content of the receiving river or sea water will be increased rather than depleted.

General Considerations

Weeds

In 8 years of operation with both the anaerobic and aerobic lagoons there has been no development of weeds, either from the bed of the tank or out from the banks. The aerobic lagoon has operated at depths of 18 in. and 3

ft. for several years and in neither case have weeds developed. In one of the lagoons at Braeside, however, silt grass (*Paspalum distichum*) has grown out from the banks into the water and has had to be removed at intervals.

Digestion of Sludge

The removal and digestion of sludge deposited in simple earth sedimentation tanks is frequently a problem. The operation of sludge lagoons under such conditions is not infrequently associated with odor troubles at certain times of the year.

Owing to the function of the anaerobic lagoon as a sedimentation and digestion, as well as B.O.D. removal unit, all raw sludge is deposited and digested in that lagoon. As a result, the sludge ultimately to be removed is completely digested before removal, thus eliminating the necessity for separate sludge digestion units. Typical analyses of raw sludge and sludge withdrawn from the anaerobic lagoons are as follows:

	Raw Sludge	Sludge from Anaerobic Lagoons
Total solids (%)	5.3	14.98
Moisture (%)	94.7	85.02
Vol. solids (%)	74.0	38.3
pH	5.8	7.5

Owing to the high pH of the contents of these units (the effluent pH is 7.5 to 8.0), there is very little odor at any time.

Lagoon Walls

It has been found essential that the material used for the aerobic lagoon walls should be of clean soil free from mixture with old sludge accumulations. Areas to be used for lagoons should also be free of sludge deposits, as the presence of sludge, either in the walls or on the bottom, may create such an oxygen demand that the lagoon may have little additional purifying capacity to treat the sewage passing through it.

Discussion

The use of lagoons for the purposes set out at the beginning of this paper —namely, the continuous treatment of dry weather flow and the intermittent treatment of storm flows—is entirely feasible. The most satisfactory procedure is preliminary treatment in an anaerobic lagoon for sedimentation, digestion, and partial B.O.D. removal, followed by aerobic lagoon treatment for complete B.O.D. removal and final stabilization of the effluent. The results obtained at Werribee indicate that sewage can be purified using an area per unit volume of flow equal to or less than that used for the methods of land treatment now in use.

The most important result of these studies has been the demonstration that extremely efficient B.O.D. removal can be achieved by passing raw sewage continuously through anaerobic lagoons, in which conditions are deliberately kept anaerobic by allowing sludge to accumulate and digest.

That B.O.D. reduction may be achieved under anaerobic conditions has been shown previously. Buswell and Hatfield (8) and Buswell and Sollo (9) have shown that various industrial wastes may be stabilized by anaerobic methane fermentation. Mallory (10) has shown that effective treatment of milk wastes is possible by passage through what is essentially a sludge digestion unit prior to activated sludge treatment. Watson (11) carried out laboratory experiments which suggested that the B.O.D. of settled sewage could be substantially reduced by agitation with digesting sludge for short periods. The B.O.D. reduction effected by a septic tank is dependent on essentially the same principle.

The present studies have demonstrated that advantage may be taken of this principle to effect, on a large scale, very considerable B.O.D. removals from raw sewage in lagoons maintained anaerobic. In lagoon treat-

ment, the efficiency of anaerobic purification is substantially greater than the aerobic process.

The use of lagoons as a form of treatment demands that they be constructed to perform the required amount of purification with the most economical use of land. The experiments described show that the purifying capacity of both forms of lagoon is best expressed as pounds of B.O.D. removed per acre per day, rather than in terms of other units. Knowing the total B.O.D. load to be treated, the area of each type of lagoon required to treat any particular B.O.D. load can be determined.

It is obvious that as the form of continuous lagoon treatment developed consists of two distinct processes, both responsible for substantial B.O.D. removal, the amount of B.O.D. removed in each step can be varied at will by altering the relative sizes of the two types of lagoon used. It is obvious, also, that the greater the proportion of purification effected in the anaerobic lagoon, the smaller will be the over-all area of land required. It would appear most efficient to carry out the whole treatment in the anaerobic lagoon. There are objections to this, however, as the effluent from the anaerobic lagoon, even if satisfactory with regard to B.O.D., would contain suspended sludge particles brought to the surface by gas bubbles rising from the sludge layer and would also be deficient in dissolved oxygen. Some treatment in an aerobic lagoon following the anaerobic stage appears desirable to overcome these two objections. The proper ratio between the two stages has yet to be determined by large-scale application of the present findings.

At present it may be said that if the proportion of B.O.D. reduction to be achieved in each stage is arbitrarily decided upon, the area of each type of lagoon to do this can be calculated. Thus, for a flow of 1 m.g.d (Imp.) and a B.O.D. of 600 p.p.m., the B.O.D. load is 6,000 lb. per day. If it be decided to remove 80 per cent of the B.O.D. in the anaerobic lagoon, the area required with a 5-day detention at summer temperatures (64° F.) is 8 acres with a depth of 2.3 ft. or greater. The area of aerobic lagoon to carry out the remainder of the purification is 18 acres, the depth in this case being unimportant. The total area required in this case is, therefore, 26 acres, which can be reduced by still further increasing the proportion of B.O.D. reduction to be achieved anaerobically. To purify the whole B.O.D. load aerobically would require 92 acres.

For the purpose of these experiments effluents from lagoon treatment were considered satisfactory if the B.O.D. of the effluent after filtering free of algae was less than 20 p.p.m. It must be realized, however, that the algal content of such effluents is not removed in practice and the B.O.D. of such effluents as discharged frequently exceeds 20 p.p.m. and may be as high as 50 p.p.m. The desirability of discharging such effluents is open to question. As the original sewage material has been stabilized and the high B.O.D. and suspended solids content is entirely due to an aftergrowth of vegetative algal matter, pollution and oxygen depletion of the receiving water by sewage organic matter could not occur. Bacteriologically, such effluents contain far fewer fecal coli than effluents from filter or activated sludge plants. There is, therefore, no objection on public health grounds to their discharge. However, the development of algae in the aerobic lagoon contents does represent a reconversion of ammonia to organic nitrogen and an increase in the organic carbon content, as shown in Table III. The possibility of this vegetative organic matter exerting an oxygen demand in the receiving water is the only possible objection which

could be raised to the discharge of these effluents. If the algae die on discharge, then an oxygen demand equivalent to the laboratory determined B.O.D. may be expected to develop and this may lead to oxygen depletion. If, as appears more reasonable, the algae do not die, but exercise their natural photo-synthetic activity, the discharge of such effluents may be expected to increase rather than deplete the oxygen content of the body of water into which they are discharged. The laboratory experiment described suggests that the latter is more likely to occur and that scientifically there is no valid objection to the discharge of algae-containing effluents. The only objection possible would be on aesthetic grounds because of their unattractive turbid appearance.

The application of lagoon treatment is obviously limited to localities where climatic conditions are suitable and relatively large areas of land are available. Where such is the case, lagoons appear to be much more economical than other forms of land treatment, both with regard to construction and operation. Apart from their suitability for supplementing present land methods at Melbourne and the increased flexibility of operation to be expected from their adoption, complete treatment of raw sewage by lagoons is an attractive alternative for small installations. With flows up to 1 m.g.d., the lagoon area required is very small, the odors usually associated with sludge digestion and disposal do not occur, the labor required for maintenance is nominal, and the process is practically foolproof.

Summary and Conclusions

1. The most satisfactory continuous form of lagoon treatment of raw sewage is by passing it first through an anaerobic lagoon for sedimentation, digestion, and partial B.O.D. removal, then through an aerobic lagoon for complete B.O.D. removal and stabilization.

2. The purification effected in anaerobic lagoons is due to the presence of a digesting sludge layer deposited on the bottom of the lagoon. These units should only be desludged at intervals of several years. The sludge requires no further digestion, is high in solids and can be dried readily.

3. The purifying capacity or performance of anaerobic lagoons is much greater than that of the orthodox oxidation pond or aerobic lagoon. Under Melbourne conditions with a detention of 5 days, it is 600 lb. B.O.D. per acre per day at summer temperatures (64° F.) and 450 lb. B.O.D. per acre per day in winter (52° F.). The purifying capacity is affected by the B.O.D. load applied, temperature, and probably by lagoon volume (or detention time). In the present series of experiments the optimum detention time in these units was 5 days.

4. The purifying capacity of the aerobic lagoon increases with increasing B.O.D. load up to a value of 82 lb. B.O.D. per acre per day. Increased loading beyond this value results in decreased performance.

5. When the lagoon is operated to give its maximum purifying capacity the effluent B.O.D. is not satisfactory. The maximum performance to give a satisfactory effluent is 65 lb. B.O.D. per acre per day and it is this value which should be used for design purposes. It is largely independent of depth and temperature conditions.

6. The presence of algae in the aerobic lagoon probably increases its capacity for purification.

7. Apart from their unattractive appearance, there is no grounds for objection to the discharge of algae-containing lagoon effluents to river or sea water, as they tend to increase rather than deplete the oxygen content of the receiving water.

8. Partially purified filter and land treatment effluents can be completely

purified by continuous treatment in aerobic lagoons. The purifying capacity treating a filter effluent with a B.O.D. of 30.6 p.p.m. is similar to, but somewhat lower than that for raw sewages (41.7 lb. B.O.D. per acre per day).

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SEWER RENTALS CHARGED BY 273 CITIES

More cities are utilizing sewer service charges to finance the disposal of sewage, the International City Managers' Association reports.

At least 273 cities of more than 10,000 population have now dropped expenditures for sewage disposal from their general tax budgets, according to statistics gathered by the International City Managers' Association for the "1950 Municipal Year Book." Collections from sewer rentals totaled more than $25,000,000 in 1948—the last year all cities reported total collections.

Camden, N. J., was the largest city to set up sewer service charges in 1949. In effect less than a year, the rental charge brought in revenue of more than $227,000.

Methods of computing sewer charges differ widely. The more popular, as revealed by the Year Book survey are: on metered water consumption; on a fixed per cent of the water bill; by fixed uniform rates; on the number of plumbing fixtures; and on the number of sewer connections. Most cities that have adopted sewer rentals assess charges against residential as well as commercial sewer users.

Industrial Wastes

FORUM ON INDUSTRIAL WASTE PROBLEMS*

(Cannery, Milk, and Food Products; Chemical; Oil Refinery; Paper Mill; Plating and Metallurgical; Textile; and Tanning)

Conducted by STUART E. COBURN

CANNERY, MILK, AND FOOD PRODUCTS

Effects and Treatment

(CHARLES C. AGAR)

In considering the disposal of wastes from cannery, milk, and other food products, whether separately or in conjunction with municipal sanitary sewage, the problems of treatment are essentially the same. However, in a large community, the effects of such wastes may be minimized. In a small community, the treatment and disposal of these wastes is frequently the governing factor in the design and operation of a treatment works and must follow generally the procedures recognized for separate disposal of such wastes.

In New York State there are considerably more than 35,000 manufacturing industries; it is estimated that some 800, or more than 2 per cent, are producing industrial wastes which have a material direct or indirect effect on the pollution of the waters of the State. Of this number, approximately 200 industries fall within the general category of food processing wastes. The estimates include both the separate discharge of wastes into streams and those discharged through a municipal sewer system. In a 1947 survey of the principal causes of stream pollution, the New York State Health Department found that of the 549 instances of stream pollution, 308 had industrial wastes as the major contributing factor. Of these, 103, or one-third of the total due to industrial wastes, were attributed to the discharge of milk wastes, 38 to cannery wastes, and 7 to abattoir or packing wastes.

These figures do not, of course, indicate the magnitude of the pollutional load on the streams of the State, but they do show a numerical preponderance of cases of stream pollution resulting from milk, cannery, and food processing plants. There are, of course, many other types of food processing carried out in the industries of the State, but many of these are located in municipalities where their effect is noticeably less than in the case of direct discharge.

It is not the intent of this brief discussion to review the various effects of such wastes on a municipal sewage treatment plant. Suffice it to say that there are many complications possible in handling such wastes in the smaller plants or in those not specifically designed to treat such wastes.

General Effects

Food processing wastes can have a serious effect in the pollution of a stream. In the first place, food is pri-

* From transcript, 22nd Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; Oct. 17-20, 1949.

marily organic in nature. It is, therefore, subject to bacterial decomposition. The inorganic content is quantitatively a very small proportion of the total solid content.

From the accounts of fish kills by the discharge of milk or cannery wastes into streams it might be assumed that such materials are poisons. This, however, is not the case, as oxygen depletion is the usual cause of fish kills where food processing wastes are concerned. The next step is anaerobic digestion, the type of decomposition which results in the blackening of streams and the development of foul odors.

Any material, whether from natural sources or from industrial processes, entering or discharging into a stream changes the character of the receiving waters. Such discharge may be detrimental or beneficial, depending on the nature, relative volume, and characteristics of the material discharged. In many cases, organic wastes may not be harmful; in small quantities they may even be beneficial by furnishing food for aquatic life.

To obtain some idea of the best approach to the treatment and disposal of food processing wastes, it is well to consider what may be referred to as minimum objectives for effluents to be discharged into the waters of a stream. It is believed reasonable that before a waste is discharged there should be removed from it:

1. Practically all settleable solids.
2. All floating solids or other materials not of natural origin.
3. Oxygen-demanding ingredients to the extent that the remainder will not reduce the dissolved oxygen content of the receiving waters below a value of 4 to 5 p.p.m., the approximate minimum considered necessary for the maintenance of fish and normal aquatic life.
4. All materials which, after admixture, may create conditions in the receiving stream toxic or inimical to man, fish, or normal aquatic life.

It has been estimated that more than 90 per cent of the instances of major stream pollution in New York State could be corrected by compliance with the above objectives. The final degree of treatment, of course, will depend on the recognized uses of the receiving waters, as the stream is the point where the effectiveness of treatment must be judged.

Milk Wastes

In the case of wastes from the milk industry, practical and economical methods of milk waste treatment are known and are being used. However, good housekeeping within the milk plant itself is the starting point for solving many milk wastes disposal problems.

Reduction of milk losses by conservation methods in many cases will solve a disposal problem. As a simple example, the installation of a "drip saver" in a milk receiving station will frequently reduce the solids loss by as much as 50 per cent. If it be remembered that a pound of milk solids is approximately equal to a pound of B.O.D., some idea is given of the big reduction accomplished. If, in addition to the drip saver, the initial rinse water from a fine jet spray is caught and separately disposed of along with initial wash water and drainage from the equipment, the over-all reduction in organic load may be as much as 90 per cent. It is certainly less expensive to make these savings than it is to construct and operate a waste treatment plant to remove the solids before discharge to the stream.

It is believed entirely uneconomical to attempt to treat by conventional methods milk wastes having a high solid content (skim milk, buttermilk or whey). These should not be admitted to any milk waste treatment plant, as the capital and operational costs to

treat such wastes are far more than to haul them to a by-product plant, or to isolated farm land for disposal, or to return them to the farmer for animal feeding purposes.

After milk solids losses have been brought to an irreducible minimum within the plant, treatment methods can be considered for the remaining wastes, if still required. In this connection, the discharge of milk wastes from an aerated holding tank over a 24-hr. period deserves consideration in reducing the peak loads on a stream where the plant operations are intermittent or for brief periods each day.

Milk wastes treatment today is based almost entirely on biological processes of oxidation, usually by trickling filters (preferably recirculating type) or activated sludge units, frequently without primary sedimentation.

Canning and Freezing Plants

Wastes from canning and freezing operations provide a more complex problem of disposal because of the wide variety of products and resulting wastes, seasonal operations, and the continuing centralization and enlargement of existing plants. Treatment becomes a specialized and independent problem for most canneries, taking into account the flexibility needed to handle the variety of wastes produced during an operating season.

There is no one known treatment method that can be considered satisfactory for all types of cannery wastes. However, the essential elements of treatment follow those indicated under the disposal of milk wastes. Removal of grosser solids by mechanical means, such as fine screens, is considered essential. Vibrating screens have found a definite and valuable place in initial treatment of vegetable and fruit processing wastes. The common type of screens in usage (20- to 40-mesh) operate efficiently in reducing the load on subsequent treatment units.

Removal of settleable solids, including floating solids, is also a generally recognized process for such wastes. The efficiency of solids removal in a settling tank can usually be greatly increased by the addition of coagulating chemicals, with subsequent mixing and flocculation before settling. In many instances, biological or secondary treatment may be necessary.

Inasmuch as many canneries operate during a comparatively short season, it is sometimes difficult to justify economically the installation of more than a minimum degree of treatment. Where adequate land areas are available, lagooning is probably the most economical method of handling the wastes from seasonal canneries or food processing plants. Several instances have been reported where sodium nitrate was used in conjunction with lagoons to reduce odors and aid in stabilization. There is no question that sodium nitrate is very effective for the purpose intended. However, the reduction of sodium nitrate results in an increase in the ammonia content and may become a serious factor in the ultimate discharge of a lagoon waste into a stream. Relatively small concentrations of ammonia in an alkaline water are toxic to fish life. Instances are known of toxic concentrations as low as 2.0 p.p.m. in a water having a pH of 8.2.

Some of the vegetables producing strong wastes, difficult to treat, include peas, tomatoes, beets, carrots, corn, squash, and beans. Among fruits, peaches, cherries, grapes, and apples present the commonest problems. Incidentally, the waste from apple processing plants is frequently an inhibiting or retarding factor in some biological processes, particularly in digestion tanks.

Abattoir and Packing Wastes

The characteristics of the wastes from abattoirs and meat packing plants

are similar regardless of the size of the plant. Most of the large plants are located in urban areas, whereas smaller plants are more frequently in rural sections where the waste disposal can be a serious problem. From the stream pollution standpoint, the principal ingredients are grease, blood, hair, paunch manure, and fleshings.

As is true in the milk industry, good housekeeping is an important factor in the volume and concentration of wastes discharged. Some plants are careful to avoid losses and utilize all waste materials possible. The wastes from such plants are weaker and less objectionable than those where careless procedures are in vogue.

Treatment methods may consist of lagooning, screening and sedimentation, chemical precipitation, or settling tanks followed by trickling filters or activated sludge units.

Discussion

D. E. Bloodgood, Lafayette, Ind.:—Do you allow the operation of lagoons for canning plant waste in New York State, with the addition of nitrate?

Mr. Agar:—Yes, providing they will not create any nuisance. The only purpose of nitrate is to prevent odor nuisance in the vicinity of habitation. Where habitation is considerably removed, canning plant lagoons are operated without the addition of nitrate.

C. N. Stutz, Salt Lake City, Utah:—A tomato canning factory in Ogden, Utah, used Cloroben this year to reduce odor nuisance, and it worked quite successfully. It was the first year it was tried.

H. H. Black, Cincinnati, Ohio:—In answer to Professor Bloodgood's question, some of the lagoons are a mile or so away from town and handle such large volumes that sodium nitrate requirements would be quite expensive.

As far as Illinois is concerned, there were a few canneries during World War II that were pretty well sold on the use of sodium nitrate. Those, however, were the ones who had lagoons right next to town, and the sole purpose, at that time, was for odor control. More recently, the value of sodium nitrate has been appreciated as a nutrient for biological growth, which certainly adds to the weight of breakdown and natural purification. I think there are states that will allow lagooning without sodium nitrate.

CHEMICAL WASTES

Waste Reduction in a Chemical Plant

(B. W. Dickerson)

Although the wastes resulting from manufacturing operations in the chemical industry are many and varied, they can be fairly well classified into five general divisions as follows:

1. Insoluble inorganic substances.
2. Inorganic acids and alkalies.
3. Soluble inorganic substances.
4. Soluble organic substances.
5. Insoluble organic compounds (tars and oils).

The action of the individual groups on the receiving stream varies with the type, the resultant effect being a stifling of aquatic and biological life to the point where the stream may become a foul and obnoxious watercourse unfit for industrial or recreational use. To eliminate this condition pollution abatement is most essential.

Inasmuch as the average chemical plant effluent is a composite of the wastes from several operations, it will contain portions of one or more of the divisions noted above. If pollution abatement is to be promulgated, it is easily seen that unless a carefully coordinated program is set up for a study of the problem, considerable time and expense can be wasted uselessly.

This discussion outlines the steps necessary for reducing the waste problem in an existing plant. Because this matter is of such paramount importance in the chemical industry, the Manufacturing Chemists Association has set up a Stream Pollution Abatement Committee which has given considerable thought to the problem and has developed Manual W-1, entitled "Organization and Methods for Investigating Wastes in Relation to Water Pollution." The following suggested steps are condensed from this manual:

1. Select a tactful, chemically trained man to supervise the work.

2. Provide adequate assistance, if possible also trained.

3. Provide the necessary facilities for making analyses of plant wastes.

4. Provide facilities for obtaining samples from the main plant sewer, individual sewers, and the stream into which wastes are discharged.

5. Collect basic data by making analyses on the main plant waste discharge and on sewers from individual operations; calculating material balances on all raw materials to locate losses; and obtaining data on the volume of waste, minimum and average flow of the receiving stream, and specific information on the conditions of the receiving stream. The latter should include determinations, on the basis of samples from the stream, as to dissolved oxygen, B.O.D., pH, alkalinity or acidity, temperature, taste and odor, settleable solids, and total dissolved solids. The samples should be taken from above and below the point at which the plant waste is discharged.

6. Solicit suggestions for re-use or recovery of waste so that operating supervision will be informed of efforts on the problem.

7. Review published data to collect helpful information on the results of other work. A bibliography of material on the subject was published in 1947.*

8. Prepare a work program, including a study program prepared on the basis of information concerning the source and magnitude of the various wastes, and on ideas and suggestions for waste recovery. This should be directed toward making the recoveries which require the least change in process or the smallest investment in equipment.

9. Provide the necessary funds, particularly for either laboratory or small-scale tests of suggested recovery methods before they can be applied to plant operation.

10. Provide engineering and technical assistance for the man in charge of the waste recovery program, who will frequently require assistance in developing pieces of recovery equipment or changes in process.

11. Require frequent reports. Frequent letters should be submitted reporting conditions needing correction, and outlining ideas and suggestions for reducing waste. Additionally, periodic reports should be made on progress in waste recovery. These letters and reports serve the functions of keeping before the operating organization the need for waste reduction, and building up a permanent record of company diligence in the study of its waste problem, and of the progress being made in reducing the amount of waste from the plant.

12. Insist on good records, in addition to the letters and reports, on such matters as waste analyses, analyses of the receiving waters, waste flow, stream flow, installations to save materials made during and prior to the waste recovery program, and legislative activity.

13. Sponsor meetings for discussion

* Hess, R. W., "Bibliography on Chemical Wastes. Wastes from the Chemical Industry in Relation to Water Pollution, 1937 to the Present." *Ind. and Eng. Chem.*, **39**, 676 (1947).

of waste problems. Occasional meetings attended by representatives from the technical, operating, and engineering departments for the purpose of discussing particular problems connected with waste recovery will develop useful ideas, and give the man in charge of the program a chance to gain the cooperation of plant personnel.

14. Cooperate with representatives of control agencies. The men responsible for the enforcement of pollution laws wish to cooperate with industry. It will be mutually helpful to become acquainted with these men and to work with them cooperatively in seeking to solve pollution problems. This approach has the advantage of keeping enforcement officials advised of the progress being made, and strengthens their position in responding to public inquiries about the abatement of stream pollution. As public opinion is essentially the force that has aroused present interest in stream pollution control, the public deserves to be informed about efforts under way to reduce pollution, and the progress achieved.

15. Cooperate with other industrial representatives, as much is to be gained, by an interchange of technical information on like problems, through membership and participation in technical societies and through trade associations where provisions have been made for such an exchange of information.

16. Study treatment methods after the recovery program waste is on a workable basis. As treatment methods are developed, they may be used to determine the investment required if it should become necessary to treat a part of the plant waste to prevent excessive pollution. The degree of treatment will be determined by the size of the plant, its location with relation to potable water supplies, and the size of the receiving stream. Careful investigation should be made of the possibility for discharging industrial waste, or acceptable fractions, either as produced or after pretreatment, into a municipal system for joint treatment at the city's plant. Such a plan, however, requires an accurate knowledge of the industrial waste, and careful consideration should be given to the effect which the addition of such waste will have on the operation of the municipal treatment plant.

17. Determine the costs of less attractive recovery schemes. Certain waste recovery methods will require the expenditure of more money than can be justified on a savings basis. Such methods should be carefully evaluated and compared with the cost of facilities required for bringing about an equivalent reduction in the amount of waste through treatment. Generally, such a comparison will favor the recovery method, as there will be a small return on this investment, whereas no return can be expected from money invested in facilities for waste treatment.

18. Dispose of sanitary wastes by collecting them separately, depending on conditions and methods of treatment of process wastes. They should be treated before discharge to a stream, or put into a municipal sewer for disposal by the city.

With such a program, properly executed, any organization should be able to handle its waste pollution problem in an economical and satisfactory manner.

Control of New Pollution

(Lyman Cox)

In the chemical industry, an aggressive pollution control program is part of many other industrial endeavors or areas of specialized direction and effort. To name a few, waste disposal must be carefully considered in research and new product development, in design and plant construction, in plant site selection, in manufacturing

and maintenance, and in employee and community relations.

This being the case, efforts in a large company to forestall new pollution are not easily reduced to the plant level and must, therefore, be handled on a company-wide basis. This situation exists because research, process development and design may be handled at a central location for the whole company, or may be divided between a central group, a consulting engineer, or scattered plant groups. In the final analysis, the control of new pollution is accomplished only by designing the necessary waste recovery and treatment facilities as an integral part of the new plant or addition.

Plant Design

If the designer wishes to keep the cost of treating facilities to a minimum, there are many things he can do in selecting equipment to minimize the quantity of waste. Depending on the particular process, it may be desirable to avoid the use of direct steam distillation because of the diluting effect obtained. Some type of closed heater may very well prove more economical when waste disposal is taken into consideration, as sufficiently concentrated waste can usually be burned. Another piece of equipment that often introduces additional quantities of waste into the plant sewer system is the barometric condenser. It is quite evident that volatile by-products will be diluted with large volumes of water if a direct-type condenser is used, whereas a tubular condenser or surface condenser would condense the volatile material in concentrated form. Other important points to consider in this same connection are leaks, spills, and periodic clean-ups. If careful plans are made to keep materials out of the plant sewer, an unnecessary load on the waste-treating equipment can be avoided. Pieces of equipment to which special features may have to be added by the designer to avoid pollution are evaporators, filters, decanters, and other types of separators.

To give a few examples of what is meant, a standard evaporator may not include an entrainment separator. If the material being concentrated in the evaporator is one which would be objectionable in the waste stream, the designer should add a special device to eliminate, or at least greatly reduce, the carry-over of material. Simply draining a filter when it is to be backwashed or dressed may not be adequate from the standpoint of waste elimination. The designer may find that special features should be incorporated to permit a preliminary washing operation for recovering as much of the filtrate as possible. Special attention should also be given to tanks used to separate crystals from the mother liquor. Several small batches of wash water may have to be used to avoid loss of mother liquor and resulting pollution. Other examples could be cited, but these serve to illustrate the important part that the designer can play in reducing waste.

Site Selection

The selection of a suitable site for the new plant is also of great importance, as no amount of treatment will avoid pollution if the site provides inadequate dilution for the irreducible minimum of waste that will have to be discharged. Industry, therefore, must select new locations with due regard to pollution control.

This subject and others relating to water pollution abatement have been treated in the manual cited by Mr. Dickerson. Inasmuch as the information contained in this manual represents the combined opinion of a number of men from the chemical industry who are at work on the waste problem, the following from the section dealing with new locations should be of interest.

"When a company decides to build a new plant, or to enlarge an existing one, careful consideration of the factors involved in waste disposal is dictated by law in many states. Whether so dictated or not, it is essential that investigation be made of local conditions, requirements, and trends concerning waste disposal, so that the design of the plant will include the facilities required for abating the discharge of excessive amounts of waste. Factors which must be considered in the design of new facilities are indicated in the following outline:

1. Determine condition and flow of receiving water at location under consideration.
2. Determine local pollution control requirements.
3. From information on type and amount of waste, determine whether acceptable conditions can be obtained by a reasonable expenditure on waste recovery and treatment equipment when compared to other factors concerning the site.
4. Determine whether available diluting water would limit the size of a plant at the location under consideration.
5. On the basis of preliminary agreements with local control authority, prepare complete plans to meet requirements for disposal of sanitary sewage and industrial waste.
6. Where required, obtain formal approval of plans for treatment works from pollution control authority. On structures projecting into a navigable body of water, obtain the approval of the War Department.
7. Prepare a description of the facilities for pollution control, including information as to the requirements that must be met at the new location, so that personnel later charged with the responsibility for operating the plant will understand the factors involved in the disposal of waste.

"When additions are to be built at an existing plant, the above considerations must be given attention. However, under these circumstances, a considerable amount of information on the receiving water and local requirements should already be available."

Combined Treatment

Another possibility which should be investigated is combined treatment of industrial waste and municipal sewage. If this is contemplated, discussions should be held with the city officials who are responsible for the operation of the municipal sewage treatment plant, so that definite agreements concerning the quality and quantity of waste which can be handled at the municipal plant can be reached. Industrial waste can be satisfactorily treated with municipal sewage, provided it doesn't overload the municipal plant or contain sufficient quantities of toxic materials to upset the treatment process. Care should also be taken to avoid the discharge of materials which will cause damage to the collecting system, which will cause clogging of the sewers, which are flammable, or which will cause objectionable gases to form in either the sewers or the treatment plant. This means that in many cases it will be necessary either to pretreat industrial waste or to segregate certain wastes for separate treatment.

Treatment by Municipal Plants

(RAYMOND W. HESS)

Diversion of industrial wastes to municipal disposal plants should be generally recognized as a method of treatment to be carefully explored in comparison with other methods of disposal. Treatment processes for sewage —chlorination, coagulation, settling, biochemical action, and sludge digestion—are applicable to many kinds of industrial wastes.

In some cases there are both technical and economic advantages in this method of disposal. Treatment methods, in the presence of sewage, are sometimes more effective and less costly. Land required for these operations is not always available at the factory site. Furthermore, the municipal disposal plant and the community, which benefits from its industries, would seem to have a responsibility to cooperate with industry in applying the advantages of municipal disposal.

Of course, in some cases, there can be definite disadvantages, both technically and economically, to this method of disposal if adopted without careful scrutiny from all angles. The problems are very complicated and merit the attention of the best techni-

cal talent available. Their solution merits close cooperation between personnel of both industry and the municipal disposal plant.

In considering the suitability of diverting an industrial waste to a municipal treatment plant, in comparison with other methods, the following questions command attention:

1. Will the method of disposal for the raw waste give satisfactory treatment?
2. Will the raw waste be harmful to the structures and processes of the municipal disposal systems?
3. If it is concluded that this method for the raw waste would not give satisfactory treatment or that the waste would be harmful to structures or processes of the disposal plant, what kind of pretreatment would be required to overcome these objections?
4. What would be the cost and would it be prohibitive?

Suitability for Raw Wastes

In deciding on whether this method of disposal would be satisfactory for raw wastes, the following should be given consideration. Chlorination will oxidize inorganic substances (such as sulfides, sulfites, and thiosulfates); toxic substances (such as cyanides); and some organic materials, including some taste and odor producing substances. In addition, it may promote settling. Biochemical oxidation is applicable to these same substances and is generally more effective than chlorination for organic substances. Anaerobic digestion is also applicable. Many industrial organic wastes contain putrescible matter which can be separated and digested in the municipal disposal plant with production of fuel gas.

Consideration should be given to individual and groups of wastes, as well as to the combined plant effluent, even though their diversion to the municipal plant would not entirely solve the over-all problem. It is essential to know the nature of the municipal processes in order to decide on whether the objectives of the regulatory body would be met. For example, if B.O.D. reduction is the objective, the effects of the municipal process on B.O.D. reduction should be determined.

In this connection, the part played by the receiving waters should be taken into account. A higher or lesser degree of treatment may be required at the municipal disposal plant, depending on the self-purification capacity and uses of its receiving waters in comparison with those for the waters on which the industrial plant is located. At least one case can be cited in which the regulatory body prefers diversion to the municipal disposal plant, even though treatment is only partial, to discharge into a small stream from which slugs of accumulated wastes are said to be discharged occasionally into the receiving waters for the municipal disposal plant.

A study of the effects of industrial wastes on the municipal disposal plant structures and processes should take the following into account. Strong acids and alkalies will damage concrete structures and biochemical processes. Hydrogen sulfide, and sulfates which are converted to hydrogen sulfide under certain anaerobic conditions, are said to damage concrete structures. Toxic materials, such as copper and chromium, may harm biochemical processes and may remain in the disposal plant effluent to the detriment of receiving waters. Inert settleable solids may give an excessive amount of ash in sewage sludge.

Pretreatment Considerations

Obviously, if this method of disposal is not applicable to the raw waste, it is either because of the municipal disposal process not giving satisfactory treatment or because of injuring the

municipal disposal plant processes or equipment. In the former case adjustment of pH or addition of another waste may overcome the difficulty. For biochemical treatment, addition of a waste to supply a balanced biochemical nutrient merits attention. Elimination of injury to equipment and processes may be accomplished by pretreatment to adjust the pH, precipitate harmful components in solution, or remove settleable solids by well-known methods. Considerable research may be involved in identifying and eliminating harmful components.

In arriving at decisions for this method of disposal, tests should be made at sewer and disposal plant dilution with sewage. Effectiveness of treatment, extent of injury to the municipal plant, structures, and processes, requirements for pretreatment, and the cost of treatment are dependent not only on the nature and amounts of substances present in sewage but also on the extent of dilution. The presence of sewage is usually beneficial to biochemical action in industrial wastes. Corrosion of equipment by a limited amount of acid will be avoided by alkalinity of sewage. Toxic substances may be destroyed or rendered harmless by chemical action or by dilution. Chlorine demand of both the sewage and the industrial waste may be lowered when mixed together, the effect of mixing on chlorine demand being illustrated by the following:

Waste No.	Chlorine Demand (p.p.m.)		
	Standard Method	Disposal Plant Dilution with	
		Sewage	Water
174	4,340	−7,150	—
126	3,100	0	4,770
124A	30,900	17,100	26,150
127	23,400	8,850	22,100
128	23,400	14,300	20,500

These data show that the presence of sewage reduced the chlorine demand of all the industrial wastes and that in one case the industrial waste reduced the chlorine demand of the sewage. It also shows that the reduction is not due merely to dilution.

Examples of Cooperative Disposal

Following are two examples of handling an industrial waste in this manner in connection with discharge to a municipal disposal system consisting of chlorination, settling, sludge digestion, and discharge of effluent into a much larger stream than that on which the industrial plant is located.

One example is a waste liquor containing organic acids and an unidentified substance which was toxic to fish. This waste was found to be suitable for discharge into the municipal disposal system, except for acidity and toxicity. Research disclosed that use of alkali to neutralize acidity would also eliminate toxicity. The municipal disposal system reduced the other objectionable characteristics (B.O.D. and suspended organic solids) to the required extent. Careful calculations showed this method of solving the problem to be more economical than recovery of the organic acids, which would have been of some value.

The other example is a sulfide waste containing some sulfites, thiosulfates, and organic material. In this case, laboratory investigations disclosed that no pretreatment was required at sewer and disposal plant dilutions. Obviously, the chlorination process at the disposal plant eliminates the B.O.D. of sulfides, sulfites, and thiosulfates. This method of disposal was found to be less costly than treatment of the waste at its source.

In both of these cases the tax levied by the municipal disposal plant is based on volume, chlorine demand, and amount of suspended solids.

Discussion

C. H. Connell, Galveston, Tex.:—Will the reduction in chlorine demand result in any reduction of the B.O.D. of mixed materials?

Mr. Hess:—That was not determined. However, with a chlorine treatment process at the disposal plant, of course, whatever chlorine is required there should be and would be, generally, used up in reduction of the B.O.D. in the effluent.

Chairman Coburn:—I don't think it does that always. We tried some wool scouring in the laboratory, determining the B.O.D., and the chlorine demand. The more chlorine we added, the greater the demand and the B.O.D. What we were doing was changing the 5-day B.O.D., or moving the ultimate demand down into the 5-day zone.

W. S. Wise, Hartford, Conn.:—A most important element in the pollution control program seems to have been omitted by the speaker. I refer to the almost universally poor housekeeping in industrial waste treatment plants, presumably resulting from the attitude on the part of management that wastes treatment is not part of the production process, but just another headache. How does one interest management?

Mr. Cox:—That is a matter of education, just as this whole matter of stream pollution abatement has been a matter of education. You will note, in my discussion of new pollution, that even after the design of the plant had been arrived at, approved, and everything else, I considered it to be very important that a careful and detailed write-up of the reasons for, and the methods of, controlling waste be outlined for use by the men who would operate the plant. It falls right in line with the campaigns and programs that the industry carries on for such things as safety, good housekeeping, and better community and employee relations. Until they are sold on that as being an important part of their operation, you will continue to have some of these sloppily run plants.

Mr. Dickerson:—In general, we try to segregate all of our contaminated wastes and treat them. At first we had the general feeling that no real check was available as to the waste that continued to come to the treatment plant. However, we have found that we can actually tell the operating department that they are losing material by the operation of our waste treatment plant. In more than one instance we have been able to show them where they had a leaky storage tank or leaky catch pans or piping.

The picture, as I see it, is an educational one. However, as more treatment plants are placed in operation it is possible to show the other divisions of the company that they do act as a watchdog on process operations, and as a result it keeps them from becoming too sloppy.

Mr. Agar:—I would like to comment on an incident that will point out a little about the economic factor. The operator of a Vermont cheese plant gave the following information which, I think, is pertinent. He said that he had to find some better way of disposing of the waste from the cheese operation than to discharge it into the adjacent small stream. Investigation of the possibilities disclosed that he would be able to haul the whey to a by-product plant, some considerable distance away, at a cost of 50¢ per unit of measurement of whey. In return, from the by-products plant, he would receive 40¢ per unit of the material. The cost of 10¢ was far cheaper than would be the cost of any waste treatment facility he could install. In that respect, the cost of treatment may be considered to be 10¢ per unit of whey waste for that particular plant.

Question:—Did I understand that the chlorine demand was actually reduced in the sewage itself; that is to

say, that part of the chlorine demand is satisfied with this industrial waste? Or is it a matter of sewage being more valuable than water in reducing the chlorine demand of the waste?

Mr. Hess:—The point is that the sum of the chlorine demands of the waste and the sewage, made separately by the standard method, was much higher than when they were mixed together and the combined chlorine demand determined. With the same degree of dilution using water there was very little reduction.

The compounds mentioned were of two different groups. One was, in general, main components with certain organic acids, but including certain other decomposition products. The other was a type of sulfites and sulfates.

C. F. Gurnham, Medford, Mass.:—It is a well-known fact, chemically, that sodium sulfate has a chlorine demand, and so has sulfite. If mixed, sulfur is formed, which has no chlorine demand. Possibly, the materials mentioned lead to similar reactions.

W. A. Lawrance, Lewiston, Maine:—It may be that the sulfites are reacting with the organic material and not getting a satisfactory reduction. That in itself would reduce the chlorine demand.

OIL REFINERY WASTES

Pollution Abatement Problems at Petroleum Refineries

(Roy F. Weston)

The universal necessity for pollution abatement has changed the economic balance so that some materials previously wasted are now conserved and utilized. However, the force of habit of unrestricted waste discharge is strong. Restrictions placed on past practices are resented and the tendency to try to slip one over on the restrictor is prevalent. Therefore, one of the most important and foremost jobs in industry is that of educating operating personnel relative to the public relations aspects of pollution abatement and of guiding their thinking relative to the economics of waste handling, treatment, and disposal versus waste elimination or recovery and utilization. Without the operators' cooperation, a pollution abatement program is destined for failure. Without a good public relations publicity program, the best efforts and largest expenditures for pollution abatement may be unknown by an appreciative public. Therefore, another important job is that of establishing a program to inform the public of efforts, expenditures and accomplishments for their good.

In accordance with the basic philosophy that industry is obligated to manufacture and market its products at minimum cost to the public, industry must abate pollution at minimum expense. Therein lies a complex problem. Complete elimination of all pollution most certainly will not provide the desired economic answer. Therefore, some pollution must be permitted. This fact raises a number of questions. What is permissible pollution? What is the condition of the receiving stream at times of permissible pollution load? What parameters shall be used to determine such conditions? What shall be the permissible pollution load by each industrial establishment when the total permissible load on the stream has been determined? What parameters are to be used to establish the permissible load from each establishment?

A basis for the answer to some of these questions may be found in enacted legislation. However, the definitions provided are usually in such broad and general terms that they leave much for interpretation by the regulatory agency. Therefore, the above

questions must be considered by industry and regulatory agencies so that reasonable, mutually acceptable and thereby enforceable parameters, rules, and regulations may be promulgated. If industry does not actively, honestly and seriously consider the answers to the above questions and does not insist on at least advisory participation in the formulation of policies and technical details relative to such rules and regulations and their administration, then industry cannot justifiably complain of regulations imposed upon them. The answers to the above questions are so basic to the problem of pollution abatement confronting industry that they are worthy of organized industrial consideration. Those investigating the fundamentals relative to these questions should have both the guidance and support of industry as well as governmental agencies.

Local Refinery Problems

The technical problems of pollution abatement at the local refinery fall into two general categories—correction of existing waste water discharges to meet the local requirements, and maintenance of an improved waste water quality by the proper operation of established corrective procedures and facilities and the proper handling, treatment, and disposal, or prevention of new waste discharges. Obviously, these objectives must be accomplished at minimum cost.

As a result of comprehensive surveys of the sources and characteristics of wastes from refinery units, waste water discharges have been classified as follows:

1. Free oil.
2. Emulsified oil.
3. Acid wastes.
4. Alkaline waters.
5. Waste caustic.
6. Condensate waters.
7. Special chemicals.
8. Sludges and solids.
9. Clean cooling water.
10. Sanitary wastes.

As space will not permit detailed discussions of the sources and characteristics of these various types of wastes, a selected bibliography is appended for those who may be interested in additional detail.

The abatement of pollution by oil is the refiner's number one problem. Free oil originates from leaks, spills, tank drawoffs, processing operations, and maintenance and repair activities in almost every part of the refinery. It will find access to all except special process sewers and practically all storm-water sewers. Consequently, nearly all waters flowing from the refinery must be collected and passed through an oil separation device prior to discharge to a stream. In general, clean free oil may be separated from clean water to provide a satisfactory effluent. Unfortunately, both the waste oil and the waste water generally contain suspended solids, presence of which frequently results in the formation of suspended solids-oil agglomerates that make it impossible to obtain a satisfactory oil content in the effluent from an oil-water separator of reasonable size. The possible effectiveness of gravity differential separation devices may be determined by carefully handling and settling a sample and then determining the oil content of the central 50 per cent layer. A standardized procedure for running such an analysis is known as the "susceptibility to separation" test, which has proven a valuable aid in analyzing oil pollution abatement problems because it will indicate the presence of non-separable suspended solids-oil agglomerates and/or emulsions. Obviously, emulsions are not removed by gravity differential separation devices, so they must be eliminated from the sewerage system discharging to simple separation treatment facilities.

Pilot plant investigations have demonstrated that the biological filter is an effective device for removing oil from effluents containing up to 100 p.p.m. and possibly more, and that flocculation using aluminum or iron salts, either with or without coagulant aids, is a highly effective process in removing high concentrations of both suspended and emulsified oils. Full-scale plant operation of an automatic backwash sand filter has produced excellent results in treating waste waters from a tank farm and loading area handling oils of high specific gravity.

Emulsions

Oil-in-water emulsions may result from the water washing of acid-treated lubricating stocks following neutralization; from barometric condensers; from the steam distillation of crudes; from the washing of acid-treated light oils; from dewaxing processes and wax tailings tanks; from hot oil pump gland leakage; from barrel, tank, vehicle and ship cleaning operations; and from the manufacture of special chemicals. Concentrated emulsions, such as those from the water washing of lubricating oils, can best be treated at their origin by various physical and chemical processes. Others can be recirculated in closed systems for re-use, and in still other cases chemicals can be added to the water or product to prevent the formation of emulsions. In some cases, there are so many widely separated small sources of emulsion that the flocculation treatment of the plant effluent provides the most satisfactory solution to the problem. It is obvious that the solution to a specific problem cannot be expressed by a general formula.

Water-in-oil emulsions originate primarily from tank bottoms and wastewater separators. They may be resolved by heat treatment, chemical treatment, vacuum filtration through diatomaceous earth, or combinations of these procedures. Waste waters with high oil, suspended solids, and oxygen demand contents result from the heat and chemical emulsion-breaking processes.

Acid and Alkaline Wastes

Acid sludges and acidulous waters originate from the sulfuric acid treatment of lubricating and light fuel oil stocks and from alkylation processes. The acid sludges are generally hydrolyzed or decomposed for the recovery or manufacture of sulfuric acid. The acidulous waters may be used in acid manufacturing processes, but usually require treatment. Hydrofluoric acid wastes are neutralized with lime so as to form insoluble calcium fluoride precipitates.

Alkaline waters originating from the water washing of acid-treated and caustic-neutralized oil stocks are generally more troublesome because of their emulsified oil content than their alkalinity. Alkaline waters accumulate in gasoline storage tanks as a result of the caustic and water washing of that product. They contain oxygen-consuming and taste- and odor-producing compounds, as well as relatively high alkalinity; therefore, they can best be collected and treated separately.

Waste caustics originate from the caustic washing of gasoline and light fuel oils to remove hydrogen sulfide, mercaptans, and other acidic constituents. The wastes may have astronomically high odor thresholds, 5 to 20 per cent B.O.D. values, 0.5 to 3.0 per cent alkalinity concentrations, and high sulfide values. In some cases, such materials may be utilized as a source of phenolic or naphthenic compounds. In practically all cases they should be treated locally to separate the major contaminating constituents prior to discharging the water layer to the plant sewers. The separated oily layer may be utilized as a by-product or as a fuel. Under the best of pretreatment conditions the water layer

will contain high phenol and B.O.D. contents, so must be handled with caution. Fortunately, the volume of this type of waste is low. Experimental work was demonstrated that dilute waste caustics may be satisfactorily treated by biological oxidation processes.

Other Wastes

Condensate waters originating from distillate separators and running tanks are generally solutions of ammonia polysulfides. At some locations they also have high phenol contents. When diluted they produce "black water," which oxidizes, precipitates colloidal sulfur, and causes high turbidity. Air blowing of these waters will strip off ammonia and hydrogen sulfide and produce a highly turbid effluent. Good quality waste water may be produced by the alum flocculation of these air-blown effluents.

Special chemicals originating from solvent extraction processes and special chemical manufacture are generally high-cost materials. Therefore, special collection and recovery equipment can be justified.

Sludges from water treating processes, tank bottoms, acid treating operations, etc., as well as granular materials like coke, filter clay, and spent catalysts, must be kept out of the plant sewers because of causing sewer obstructions and because of the interference of suspended matter in oil separation.

Clean cooling water should not be discharged into dirty-water sewers. The re-use of such waters by recirculation over cooling towers appears to be the most economical way of handling this disposal problem. At some locations, special clean-water sewers have been used economically.

Sanitary wastes originate from locker rooms and toilet facilities located in all parts of the refinery, and from one or more centrally located restaurants or cafeterias. Large refineries confronted with the problem of providing separate sanitary sewage collection and treatment facilities have had to spend millions of dollars on this phase of waste treatment alone. Some municipalities—for example, Philadelphia—will accept neither industrial wastes nor sanitary wastes from a petroleum refinery.

In general, the refiner is confronted with the problem of large numbers of small sources of wastes, no one source being large enough to warrant localized collection, treatment, recovery, or utilization procedures, but the aggregate of all sources creating a waste water of just sufficiently obnoxious characteristics to necessitate treatment in addition to gravity differential oil separation. In some cases, the collection and segregation of a few particularly bad sources eliminates the need of secondary treatment. In all cases, the cooperation of operating personnel reduces the problem of waste treatment.

The provision of procedures and facilities adequate to handle the problem existing today is helpful, but is not the final answer to the refiner's pollution abatement problem. The petroleum industry is a dynamic industry; process changes are being made daily. It becomes necessary, then, to coordinate the activities of the research and development, engineering, operating, maintenance and repair, and waste control personnel so that each new process or process change is given due consideration relative to its pollution potential. It is necessary to maintain a continuing educational program so that operating personnel will maintain interest in keeping losses to a minimum. It is imperative that well-trained, conscientious and intelligent personnel be provided for operating the waste treatment and control facilities under the direction of a waste control group. The waste control group must be made up of interested, well-trained, competent, alert, aggressive, and congenial personnel to assure

proper cooperation with operating personnel and to insure satisfactory pollution abatement at minimum cost.

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Discussion

Question:—On the average, what can be expected, in parts per million of oil, in the effluent from an A.P.I. separator?

Mr. Weston:—The answer to that question is: How deep is a well? It depends entirely on the type of material applied to the separator. An A.P.I. separator will remove from 90 to 95 per cent of the removable oil; but there is the catch—all the oil going into the separator is not removed. Therefore, if the efficiency of the separator is determined on the basis of what goes in and what comes out, it could have zero efficiency or it could have 95 per cent efficiency, depending on the characteristics of the influent material.

We are advising all who have problems with oil separations to run the "susceptibility to separator test" previously mentioned. A sample is collected and, handled as carefully as possible, allowed to stand for one-half hour. The middle content is then removed and the same test run on it. If great separation is not apparent in the second phase, a gravity differential separator may have a chance. However, if the oil content in the second phase is too high, the separator should only be used to collect oil as an economical procedure, not as a waste treatment procedure.

W. S. Wise, Hartford, Conn.:—Usually there is a combination of the floating oil and emulsified oil. Has the oil industry done any work in trying to de-emulsify those oils, so there will be less going out into the stream?

Mr. Weston:—Emulsions originate from a number of different locations within a refinery. Where there are concentrated emulsions, of course, they are treated locally; the oil is recovered and the emulsion-free effluent is discharged in sewage. However, where the emulsion is formed within the sewers, from a large number of small sources, chemical flocculation is necessary.

C. J. Matthew, Cambridge, Mass.:—Has the oil industry done much work on the use of an effective absorbent to remove small traces of oil from pollution of streams?

Mr. Weston:—Although a little work has been done in this direction, the opinion has more or less been that degeneration of such an absorbent would probably make its use uneconomical. I know of no actual economic studies, but that has been the general impression.

In reference to the removal of traces of oil, we do have in operation an automatic backwash sand filter that is

doing an excellent job on the removal of oils of high specific gravity that will pass through an ordinary gravity differential-type separator. Also under investigation is a biological filter and, odd as it may seem, excellent oil removals are obtained.

L. H. Enslow, New York, N. Y.:—In flocculation of oil, what is the most effective chemical?

Mr. Weston:—Almost any of the flocculating agents used in water treatment plants. The only disadvantage with using alum is that it presents a relatively large floccule to start with. Addition of oil makes the floc that much larger, and the overflow rate of the tank has to be watched.

Mr. Enslow:—Is any sort of clay used?

Mr. Weston:—Yes. Clay has been tried as a weighting agent. It worked satisfactorily. Activated silicate is very effective as an acid.

R. D. Hoak, Pittsburgh, Pa.:—Would it be practical to use precipitated ferric hydroxide as an absorbent in cleaning up final traces of oil?

Mr. Weston:—Anything that will act as a coagulant can be used effectively. One of the methods for determining oil involves the absorption of oil by ferric hydroxide.

Mr. Hoak:—It has been mentioned that one of the difficulties in using absorbents was the recovery and the regeneration of the absorbent. Freshly precipitated ferric hydroxide would be an inexpensive material that would not have to be recovered.

Mr. Weston:—It still presents a disposal problem as sludge is involved.

Question:—What is being done in the petroleum industry with respect to phenol wastes? Are there any practical ways of eliminating phenols within the process?

Mr. Weston:—The biological experiments previously mentioned are for the purpose of trying to remove phenol.

Question:—Was it intended to leave the impression that biological filters could be supported by low concentrations of oil refinery wastes?

Mr. Weston:—Actually, there is in the waste organic matter that will support the growth on biological filters. The removal of oil is incidental, but the efficiency of the oil removal is good.

J. A. McCarthy, Lawrence, Mass.:—Nothing has been said about the claims being made for the use of gases in removal of oil. There has been a great deal of talk about oxygen, use of which is reported to reduce oil to less than 0.01 p.p.m.

PAPER MILL WASTES

Oxygen Demand by Permanganate Method

(Walter A. Lawrance)

The system of control of the pollution in the Androscoggin River, which is based on regulating sulfite pulp production at two widely separated paper mills and the use of sodium nitrate to river odor conditions many miles from the sources of contamination, requires as one condition of operation, a rapid method for the determination of pollution load at many sampling stations. With a variable pollution load, the presence of many dams with very different retaining times, and the efficient use of sodium nitrate require decisions based on conditions as they presently exist.

The dichromate-sulfuric acid method has been experimented with and found to yield reasonably reproducible results, but for work on the Androscoggin River the use of potassium permanganate solutions gives more information with less expenditure of time and effort than any similar test. In some laboratories, the use of permanganate to obtain oxygen-consum-

ing power of pollution has been discarded or is rarely used because the B.O.D. method yields results more in harmony with actual experience. However, examination of water from a stream containing principally industrial wastes may reveal that the B.O.D. values are misleading or require supplementing with other oxygen consumed data.

Of the many objections to the B.O.D. method, the time required to obtain results is perhaps one of the most important. A delay of 5 days may not be important where pollution loads are fairly constant and a sufficient backlog of experience is available, or where performance records are necessary. However, under rapidly changing conditions due to temperature, flow, or load, or any combination of these, a reliable rapid method is a necessity.

Permanganate in acid solution usually oxidizes more of the organic matter present in the water than do micro-organisms, but with water that is highly contaminated with sulfite liquor the hot and cold oxygen consumed values are very informative. When interpreting the results obtained by this method, consideration must be given to the fact that permanganate solution at room temperature not only oxidizes sulfides, nitrites, ferrous iron, etc., but may partially or completely oxidize some organic compounds, especially those catalyzed by manganese ions.

The permanganate method for oxygen consumed is employed with Androscoggin River water for the purpose of obtaining:

1. Rapid results. The determination may be made in less than 1 hr., and if carefully planned, 4 samples can be tested in an hour. The procedure in the 4 laboratories testing samples from this river is to determine the oxygen consumed from permanganate (4.0 g. per liter) at room temperature to a 3-min. end point, then the amount consumed hot by the usual 30-min. period of heating. No difficulty has been experienced in correlating the data from one laboratory with that of the other. For field work, a small portable gasoline stove is employed.

2. Cold values. When an effluent contains readily oxidizable inorganic compounds (such as sulfurous acid, sulfites, etc.), the magnitude of the oxygen consumed at room temperature and the decrease which occurs at definite time intervals furnish a basis for estimating the oxygen requirements for the inorganic loads in the area under investigation. In the Androscoggin Pond an increase in the cold determinations, when the dissolved oxygen is very low, indicates the appearance of hydrogen sulfide.

3. Evaluation of pollution load. The cold and hot values enable an experienced observer to evaluate the extent of the pollution load and some of its characteristics. If necessary, it is possible to do this within 1 or 2 hr. after sampling.

4. Time of passage. Oxygen consumed results have been obtained at many different stations along the Androscoggin River and Pond and used to determine the time of passage. (*Sewage Works Journal*, **20**, 5, 881; Sept., 1948.)

5. Oxygen actually utilized by the stream. The difference between the oxygen consumed values obtained at two distant locations, with due allowance for time of passage, measures the amount of oxygen utilized in that portion of the river. For distances involving 1 or 2 days, these data are often more useful than calculations made from B.O.D.'s.

6. Reaeration. Oxygen consumed data, together with those of the oxygen utilized in a given area, and dissolved oxygen entering and leaving the region, provide a basis for calculating reaeration rates.

This method, like all others, is used as an aid to judgment. The actual values obtained by any procedure are important, but unless they are appraised intelligently, they may be worthless. Man should be the master of his tests, and not their slave.

Progress of Studies

(Don E. Bloodgood)

A discussion of the disposal of the wastes from the paper industry sounds like a report on the activities of the National Council for Stream Improvement; and so it is, because the coordinated workings of this organization of 90 per cent of all paper manufacturers is practically all of the work being done on the disposal and/or utilization of paper mill wastes in America. The wastes from the manufacture of the product called "paper" are many and are all different in physical and chemical characteristics. There are the sulfite, the sulfate, and the soda processes that can be considered largely chemical. Then there are the mechanical processes (such as grinding, pressure cooking, beating, and washing). Further, there are processes that combine mechanical and chemical methods. The materials used in the manufacture of paper are wood, straw, flax, jute, hemp, rags, and old paper stock. Combinations of materials and processes result in waste waters with such different characteristics that the treatment processes employed must be modified or be entirely different in each case.

The N.C.S.I. is carrying on research dealing with the handling of the wastes from the several processes as well as studying the effects upon the streams receiving the treated, partially treated, or raw wastes. Studies have been made on the disposal of the wastes from processing rope, rag, and jute, as well as methods for treating white water (the waste water from the paper machines); on the storage oxidation process as applied to the treatment of kraft mill wastes; on the wastes from the de-inking process; on the wastes from the semi-chemical process; on the waste sulfite liquor problem (growth of fodder yeast and filamentous molds are being tested as suitable means for the disposal of this waste); and on the effect of sulfite pulping wastes on the famous Androscoggin River.

It has been found that kraft mill wastes are the only pulp and paper mill wastes that contain toxic substances that are detrimental to aquatic life. Extensive studies on the effect of these wastes on fish life have been made.

Our investigation on strawboard wastes has progressed to the second pilot plant stage. The earlier studies proved that the trickling filter was not suitable for treatment of strawboard wastes. A thorough laboratory investigation of the anaerobic treatment of strawboard waste was carried out. The results of these studies showed that strawboard waste water with 963 p.p.m. B.O.D. could be reduced to produce effluents with 80 p.p.m. B.O.D. The time taken to accomplish this was less than two days at 37° C. temperature. At 30° C., the average temperature of the waste from a mill, effluents averaging 87 p.p.m. B.O.D. were obtained with influents averaging 928 p.p.m. and detention times between 1.9 and 3.8 days. The amount of gas produced in the decomposition was directly proportional to the amount of B.O.D. removed in the process. In the pilot plant studies that have been made during the past year at the Terre Haute (Ind.) Paper Co., a more concentrated waste has been treated. The more concentrated waste (2,400 p.p.m. B.O.D.) was obtained by segregation of the beater and machine waste waters. Comparable reductions in pounds of B.O.D. per cubic foot of tank were obtained in the laboratory and pilot plant. The B.O.D. of the

effluent from the pilot plant was found to be higher in about the same proportion as the B.O.D. in the influent.

The sludge obtained in primary settling still remains a problem. It can be dewatered when treated with alum or ferric chloride, but the large quantity of lime in the sludge makes the chemical requirement very high. Further studies on sludge disposal methods must be undertaken. Suggestions for possible solutions to the sludge problem will be welcomed.

Further laboratory studies are being made to determine, if possible, exactly what are the soluble organic compounds in strawboard wastes. These compounds have been generally classified as sugars and lignin. A more complete classification may be helpful in developing more efficient methods of disposal or possible uses for these compounds.

It is apparent that it takes effort, patience, and money to make progress in the disposal of industrial wastes.

Discussion

W. S. Wise, Hartford, Conn.:—Has any work been done on B.O.D. removal by just plain sedimentation, and what can be accomplished by the addition of flocculating agents, like alum, etc.? Are any figures available on B.O.D. removal by those treatments?

W. Rudolfs, New Brunswick, N. J.:—Plain sedimentation of fiber waters, removing, say, 95 per cent of the suspended solids, reduces the B.O.D. from 17 to 22 per cent. When alum or coagulants are added, B.O.D. may be reduced as much as 35 per cent, the ultimate being some three or four results obtained at a commercial installation, where as high as 87 per cent B.O.D. reduction is claimed. The values cited varied from 17 to 87 per cent, with the average around 70 per cent. That is the extent of the known knowledge about B.O.D. removal.

Mr. Lawrance:—The maximum B.O.D. removal we have been able to obtain is somewhat lower; 25 to 30 per cent seems to be about as much reduction as we can possibly obtain by any combination of known methods.

T. R. Camp, Boston, Mass.:—Our experience in a number of paper mills indicates that the white waters are relatively insignificant as a problem. Adequate "save-alls" are usually all that is required, and it pays to put them in to refine the fiber.

The real problem is the cooker liquors, which account for from 60 to 95 per cent of the B.O.D. Very little B.O.D. is associated with the white water, and relatively small amounts of B.O.D. are associated with the second and third rinse waters. Most of it comes with the initial rinse and the cooker liquors. We have tried coagulants of various types on cooker liquors. It is found that some types of chemicals give very good clarification, but the effect on B.O.D. is relatively insignificant, both with sedimentation and with coagulation followed by sedimentation. Treatment of cooker liquors with trickling filters, and by activated sludge, will give as good removals as can be had with sewage. Addition of nutrients and phosphates makes a considerable difference. Without nutrients, B.O.D. removal is about 15 to 25 per cent by activated sludge or by trickling filters; with nutrients added, up to 95 per cent removal can be attained without much trouble.

Dr. Rudolfs:—Mr. Chairman, it is quite obvious that the B.O.D. cannot be removed from the white waters, because the B.O.D. is practically all in solution; so enough chemicals must be added to precipitate it. The use of biological methods for the removal of suspended solids does not solve the pollution problem.

Mr. Wise:—I must take issue with Mr. Camp's statement that save-alls are usually the only thing necessary in the treatment of white waters. Experience in Connecticut has demonstrated that none of the save-alls in

operation there turn out effluent with less than 1 or 1½ lb. of suspended solids per 1,000 gal. For a plant turning out 4 m.g.d. of that waste that means from 4,000 to 5,000 lb. of fibers going into the stream per day.

PLATING AND METALLURGICAL WASTES

Problems Involved

(J. E. Cooper)

It is desirable to emphasize immediately that cyanides used in the electroplating and metal-hardening industries are perhaps the most toxic waste products produced by industry. Exact toxicity values are still being determined for many cyanide salts and there is considerable disagreement among various authorities as to the limiting concentrations which can be tolerated in streams and sewage treatment plants.

Although hampered by this lack of exact knowledge, there appears to be a nation-wide desire by governmental enforcement agencies to establish specific restrictive values or limitations on the cyanid, content of industrial effluents. Without commenting on the general wisdom of establishing such specific regulations, I should like to urge strongly that representatives of the technical societies of the electro-plating and metallurgical industries involved be invited to give their counsel and assistance in the preparation and before any such regulations are adopted.

A case in point recently occurred in Michigan. Plagued by a succession of recurrent fish killings throughout the State, thought to result from the injudicious handling and disposal of plating wastes, a State regulation was tentatively proposed, designed to limit the cyanide concentration in any effluent to 1 p.p.m. and in any flowing stream to 0.1 p.p.m. At public hearings held to discuss the proposed regulation, numerous complicating considerations were advanced, with the result that the regulatory body formed a Committee, in which the industry affected was well represented, to assist in writing a more comprehensive and acceptable regulation. As yet the Committee has not completed its work, but a few points brought out during the deliberations were of such general interest that they bear repeating here.

The original draft of the regulation was framed to regulate carefully the cyanide content of rinse waters continuously discarded during normal operations. These rinse waters contain very low concentrations of plating salts and should be carefully differentiated from concentrated baths. In studying the records of the 78 or so fish killings over a period of 3 years, it was learned that not one occurred from rinse waters—all resulted from the accidental or intentional discard of strong plating baths. Thus, it would appear that the engineering effort required to handle the waste problem should be directed toward means of controlling the loss of concentrated baths, rather than toward rinse water treatment. It is along these latter lines that the Committee is now working.

Another important consideration of general application which was brought out, is the desirability of supplementing all specific standards with the laboratory method on which control of the standard will be determined. In the case of plating salts, this is extremely important, as the refinements in the laboratory methods of analysis have not as yet entirely caught up with the limitations imposed.

One of the newer approaches to reducing the waste problem in electroplating operations is the complete elimination of cyanide from the plating baths. This is brought about by substituting the pyrophosphate salts of metals in place of the metal cyanides. These salts are relatively non-toxic and much of the pollution hazard in main-

taining cyanide baths is removed. The toxicity of rinse waters is vastly reduced at the same time.

Metallurgical Wastes

Metallurgical wastes consist of all wastes produced in steel operations including those from blast furnaces, coke ovens, rolling mills, etc. Chief among this host of waste is waste steel pickling liquor, a solution of ferrous sulfate in sulfuric acid of varying strengths. The literature is replete with various disposal processes and practices; thus, only the late work representing our contribution to a solution of the problem will be mentioned.

The Ford industries have been working the past two years with the cities of Detroit and Dearborn on the use of raw waste steel pickling liquor as a sewage sludge containing agent. In this process, waste steel pickling liquor is added with lime to either primary or digested sewage sludge prior to vacuum filtration. The sludge is satisfactorily conditioned and filter yields have been consistently comparable to those obtained by using ferric chloride. The filter cake is slightly drier, and a 6-month pilot operation, handling 2,500 tons of dry solids at the Detroit sewage treatment plant, brought out no contra-indications to its use.

In general, use of pickling liquor requires two to three times as much iron as when using ferric chloride. However, this is of little consequence, as the pickling liquor is relatively so much cheaper. The additional lime used is very slight, as in conventional sludge conditioning practice excess lime is often used with ferric chloride. Little or no mechanical change is required in the sewage plants, other than increasing the available chemical storage to handle the more dilute pickling liquor.

In the steel mill, extensive changes have been required in providing stainless steel heat exchangers, pumps, and pipelines, along with acid-proof storage and loading facilities. The material is to be transported to the sewage plants by means of tank trucks.

Some of the plant-scale results of the work at Dearborn have already been reported.* Data for the 6-month plant-scale test at Detroit has not been published as yet.

The modern trend in steel pickling appears to be the use of much higher concentrations of acid, which produce faster pickling rates and apparently eliminates the undesirable inhibition effects of the ferrous sulfate. The result is a waste containing a higher acid and lower iron content, so that acid recovery processes may now become economically attractive to steel mills.

Some Plant Descriptions

(William S. Wise)

This discussion briefly describes a few of the treatment plants in operation in Connecticut, in such a way as to indicate the flexible policy of trying to fit each plant to the local conditions and to reasonable requirements of the specific receiving waterway.

Plating Wastes

One plating plant produces acid cyanide wastes in one department and alkaline cleaning and enameling wastes in another department, these wastes being carried to the treatment plant site through separate drains. The acid wastes, which have a cyanide content of about 20 p.p.m. and a pH between 1.7 and 4.0, are run into two baffled lagoons, operated in series, with a combined detention of about 72 hr. Here most of the cyanides are volatilized or hydrolyzed. The acid effluent from the second lagoon flows into the alkaline wastes drain and the mixture

* Groen, M. A., "The Use of Steel Pickling Liquors for Sewage Sludge Conditioning." *Sewage Works Journal*, **21**, 6, 1037 (Nov., 1949).

is discharged into the final large baffled lagoon where substantial neutralization takes place with precipitation of most of the metals. The final effluent reaches the river with a cyanide content usually around 1 p.p.m. and the river dilution reduces this concentration usually to 0.1 p.p.m. or less. The lagoons are located in sandy soil so that some seepage takes place. However, the seepage does not in any way affect any public or private water supply. The lagoons are usually cleaned of sediment during the summer vacation shut-down period.

Another plating plant pumps its wastes (containing chromium, cyanide, copper, zinc, and other materials) into eight 20,000-gal. circular wooden tanks equipped with propellor mixers. As each tank is filled, simple tests are run and successive additions are made of sulfuric acid, barium sulfide, and lime for cyanide and chromate reduction and precipitation of the metals, which takes place in about a 4-hr. settling period. Reduction of the high chromium content is accomplished by precipitation with beryllium sulfate. The effluent is decanted through a swivel-arm drawoff pipe to the stream. The sludge is re-used for a number of additional treatments and is finally hauled away in a tank truck for suitable disposal because of insufficient area for sludge drying beds or lagoons.

Another plating plant has just built a 20,000-g.p.d. waste treatment plant of very flexible design. The wastes are discharged into a receiving pit, from which they are pumped to one of three square, 10,000-gal., concrete tanks. Caustic soda and chlorine are added in the pump suction line for pH correction and cyanide destruction. If tests indicate insufficient treatment in the tank, the contents can be partially or entirely recirculated or mixed with the raw wastes and retreated, or additional chemicals can be added to the tank and the contents mixed with a propellor mixer, and then allowed to settle for a period sufficient to get complete precipitation. The effluent is decanted through a series of fixed drawoff pipes to the stream and the sludge is dried on sludge beds.

Another installation is being designed for the treatment of wastes from the plating department of a large plant on the basis of treating only the spent concentrated wastes. A thorough study and investigation showed that the rinse waters were sufficiently dilute in cyanide and metal content to permit their discharge into the large receiving river without treatment. Gravity drawoff pipes will be completely eliminated from the concentrated plating and treating baths and the contents, when spent, will be transferred from the bath to a portable tank by means of a portable pump, both mounted on an industrial truck. They will then be transported to the proper tanks at the treatment plant, where chlorine, sulfur dioxide, and lime will be used to remove cyanides and metals. The clarified effluent will be discharged to the rinse water drain and the sludge to lagoons.

Pickling Wastes

For the past fifteen years steel pickling wastes, both spent acids and rinse waters, have been treated in one plant whose effluent discharges to a small trout fishing stream. The wastes are equalized in a large tank, then lime is continuously added, as they flow to the treatment plant for flash mixing and settling in a mechanically cleaned clarifier. The effluent is discharged directly to the stream and the sludge is run to lagoons. A considerable amount of the dried sludge is used for the purification of illuminating gas.

Steel pickling wastes at another plant are being continuously neutralized by automatic pH control devices operating a lime feeder. The neutral-

ized wastes are run to lagoons and the clarified supernatant, which does not seep into the sandy soil, overflows to a stream. The sludge will be removed from the lagoons as the needs require.

At still another plant, brass pickling wastes are being neutralized to a pH of about 5.0 and discharged to the municipal sewer system. At this pH the wastes will not be detrimental to the sewer system and it is expected that the metals will be beneficial to the dewatering of the raw sludge by vacuum filters at the new sewage treatment plant under construction. The neutralization is accomplished continuously by pH control equipment automatically operating a lime feeder.

Pickling wastes from the large brass and copper plants using millions of gallons of water per day have been successfully treated in pilot plants using lime for neutralization and sulfur dioxide for reducing the hexavalent chromium to the trivalent form. The sludge has been processed in the laboratory and the copper, zinc, and chromium recovered for re-use. The process appears practical and promising, with the value of the recovered metals nearly equivalent to the treatment cost. Plans are being made for installing a metals recovery pilot plant for obtaining more complete data.

Ion exchange processes have been utilized on a small scale for concentrating the metals in the dilute rinse waters from brass and copper plants. Almost complete removal of copper and zinc was found. However, substantial amounts of hexavalent chromium in the wastes caused considerable corrosion of the resins, with resulting poor removals. This work is being continued and the solution to some of these difficulties appears imminent. Investigations have shown that about 85 per cent of the acids and metals are lost in the large volumes of dilute rinse waters and only 15 per cent in the spent acids. Concentration through ion exchange processes, therefore, would be very beneficial in the treatment and recovery of these wastes.

A number of industrial waste treatment processes have been developed and a number of plants have been designed, built, and operated. Experience has shown that these phases of the problem are comparatively simple to solve, as compared to the difficulty of securing management's proper viewpoint toward waste treatment and good operation and maintenance of the plants after they are constructed. Some excellently designed plants have given poor results because of poor operation and maintenance, whereas some plants not so well designed have produced good results with good attention. Probably the most difficult phase of industrial waste treatment and pollution abatement is in getting management to consider the cost of treatment as much a part of the production cost as water, power, raw materials, labor, etc. It is equally important to operate and maintain the waste treatment plant with the same care as is used to operate and maintain production equipment.

Discussion

C. F. Gurnham, Medford, Mass.:—The American Electroplating Society has been working on this general subject for some time. Lack of a satisfactory means of analysis for cyanides has been one of the major problems.

H. Gladys Swope, Chicago, Ill.:—Has Mr. Wise anything to say regarding the amount of cyanide and the amount of chromium that can be discharged into water courses? Also, has either Mr. Cooper or Mr. Wise done any work on the treatment of copper and chromium cyanide waste by ion exchange?

Mr. Wise:—In Connecticut we have no definite standards for the discharging of types of wastes in particular streams. Those regulations are de-

termined by the specific plant on the specific stream.

I am more and more inclined to believe that maybe we are a little too much concerned about the discharge of cyanides into streams, in the sense that cyanide may not remain as a cyanide for very long after it reaches the stream. Due to hydrolysis or some chemical change, it will be converted to a less toxic form, and maybe we have been too picayunish about the very low concentration requirement before the waste can be put into the stream.

As concerns ion exchange, we have done a considerable amount of work in the Yale University research laboratory. The chromium in wastes is usually approximately 50 per cent hexavalent and 50 per cent trivalent. The hexavalent form tended to cause a rapid disintegration of the proximate residues used for ion exchange. However, the study is being continued and it looks as though maybe the problem can be solved or, at least, it may prove to be less troublesome than it has appeared. The residues will completely remove the copper and the zinc, and even under the corrosion of some of the residues, it removed a large percentage of the chromium.

L. F. Oeming, Lansing, Mich.:—In the lagoons mentioned by Mr. Wise, is any protection provided against percolation into the soil and contamination of the water supplies? In Michigan, several municipal ground water supplies have been lost through contamination by seepage from such lagoons.

Mr. Wise:—No problem is involved, as far as the contamination of well water is concerned, in the cases mentioned. There are no wells in the immediate vicinity.

In each case, the lagoons are close to the small water course. Undoubtedly, the wastes do seep into the stream, because the natural course of the ground water is toward the stream, but the sampling analyses don't indicate that it is affected in any way.

A. K. Graham, Jenkintown, Pa.:—We are dealing with a very complicated problem, as far as the electroplaters are concerned. Different plants have different compositions of wastes and different local problems to meet. A very meager amount of data is available.

There should be very close liaison between such a group as this and those who are interested in the effect of what we do on the disposal of sanitary and other wastes, as well as the people who are interested in supplying healthful water. Requirements seem to vary considerably in different areas. It would be very helpful to those of us concerned with the problems of plating waste disposal if a standard and limit could be established more definitely, so that we might have some knowledge of what the leeway might be and what the restrictions might be.

L. Cox, Wilmington, Del.:—I think that the view Mr. Wise takes of the matter is quite sound, because of the variations of the treatments in local streams, because of the difference in the volume of sewage, and so on. Any attempt to establish limiting values for all effluents, everywhere, would be a great mistake.

L. H. Enslow, New York, N. Y.:—In the matter of lagooning, cyanide and metallic wastes are unlike organic polluting materials; they do not disappear by any biological action. Therefore, the real danger of this whole picture is that lagoons will pollute the underground water strata. Once this has been done, there is no hope; that acid can never be recovered. Therefore, lagoons have distinct limitations in cyanide and metallic wastes disposal when it comes to the effect on the water supply of this country.

C. N. Sawyer, Boston, Mass.:—The fact is that we don't have the facts and data to establish reasonable standards.

In some of the work being done at Massachusetts Institute of Technology, we are hoping to provide some of the facts and data, so that we can at least establish some standards in streams. The quality of an effluent need not be known, as long as it is sufficiently diluted. If the fish in the stream are to be protected, we have pretty good evidence to believe that the limiting concentration of cyanides is 0.1 p.p.m. If the fish and aquatic life are of no concern, the evidence indicates that the concentration of cyanide in the stream may be as high as 1 p.p.m. without interfering seriously with the chemical reactions responsible for stabilization of organic matter.

TEXTILE WASTES

Problems Involved

(JOSEPH A. MCCARTHY)

Wool Scouring

It seems that further study of textile wastes simply presents more and more problems; however, the most important still seems to be that of wool scouring wastes. The most encouraging feature of this problem is the growing realization by the manufacturers of the intensity of the amount of waste in terms of grease, B.O.D., and solids discharging into the streams, and the large amount of valuable grease, soda, and other materials being thrown away. The last consideration, of course, is very important, as it presents the possibility of the manufacturer making a profit from his cooperation in reducing stream pollution.

These considerations have brought about joint action in New England by a large group of wool scourers. Plans are well advanced for a cooperative study of the wool scouring problem, to be conducted jointly by the Lowell Textile Institute and the Lawrence Experiment Station of the Massachusetts Department of Public Health. The project would include a thorough restudy of the present-day processes from the viewpoint of the manufacturers with regard to re-use, perhaps, of wool scouring liquor, which is well-known to contain large amounts of soaps and soda, and with a view to otherwise reducing the load on the streams. The next step will be a more thorough investigation of the grease discharged in the process, both quantitatively and qualitatively. This has arisen from the realization that there has been a great loss of the more valuable fractions of the grease. By the present acid-cracking and hot pressing method, practically the only recovery has been of greasy materials melting at considerably less than the boiling point of water. Therefore, included in the project will be an investigation of methods of recovering the higher melting-point waxes.

In addition, the Lawrence Experiment Station has been cooperating with one of the large wool scouring plants in a project for re-use of wool scouring liquor after centrifuging. This plant is also conducting a study on grease balance and the investigation has already uncovered the possibility that changes may occur in the grease (such as oxidation of fatty alcohols to fatty acids). There seems to be a fair chance that either coagulation or precipitation may yield considerably greater recovery of valuable grease than present methods.

At present there are three full-scale treatment plants in operation in Massachusetts. One is using hypochlorite treatment with grease recovery. Another, using calcium chloride, has shown very satisfactory results in reducing the load on the stream; no attempt has been made to recover

grease. In addition, there are one or two treatment plants in which scourings are treated with other textile wastes.

The calcium chloride-carbon dioxide process (see *Sewage Works Journal*, 21, 1, 75; Jan., 1949) is still being studied both by the manufacturers of calcium chloride and the Lawrence Experiment Station. Some work has been done on the step addition of calcium chloride, which indicates considerable savings in coagulants. Experiments have been made on the combined use of potato starch and calcium chloride with the hope that the starch might provide a satisfactory nucleus for floc formation; thus far the results are extremely indefinite. We have also done a considerable amount of work and plan to have two full-scale experiments carried on doing either pressure or vacuum filtration of the sludge prepared by calcium chloride cracking. Very small-scale experiments indicate the possibility of fractionating the recovered grease.

Other Textile Wastes

Wastes resulting from dyeing and dye-finishing have been further studied; a fairly large-scale plant using biological treatment of such wastes is ready for operation. There seems to be a marked similarity between some chemical manufacturing wastes and those resulting from dyeing and dye-finishing, in that both contain large amounts of color, which is more or less difficult to break up, and have considerable amounts of bactericidal materials. Likewise, both wastes are fairly low in B.O.D. and neither waste is amenable, ordinarily, to chemical coagulation. The wastes from several small plants making small-quantity lots of dyes, as well as other textile supplies, have presented some rather difficult problems.

A large bleachery in Massachusetts is attempting to dispose of its waste by biological treatment following neutralization. The results indicate that extremely accurate pH control will be necessary. Experiments indicate that neutralization of the highly alkaline kier wastes before mixing with other less alkaline wastes is more effective in producing satisfactory sedimentation than is acid treatment of the wastes after mixing. Addition of ammonia to the settled wastes to produce a C/N ratio (or, more exactly, a B.O.D./Kjeldahl ratio) of 20:1, is bringing about a satisfactory growth in this filter, with promising results in removal of B.O.D. and suspended solids.

Wastes from the manufacture of rayon, as well as the very popular mixtures of rayon textiles, present rather difficult wastes. However, a comparative study of these wastes with waste resulting from plastic manufacture show many parallels; and the plastic wastes in one or two instances show surprisingly good results from biological treatment after neutralization.

Effect of Detergents

The growing use of non-ionic detergents in the textile industries is having a serious effect as far as sedimentation is concerned. In one plant, in which approximately 50 per cent of the soap formerly used has been replaced by a non-ionic detergent, a fair amount of removal was formerly obtained with approximately 2-hr. settling. Results now seem to indicate a removal of less than 5 per cent of suspended solids, with a large proportion of emulsions. It is interesting to note that in wool scouring plants where a large part, or in some cases all, of the soap has been replaced by these non-ionic detergents, more satisfactory grease recovery has been obtained.

TANNING WASTES

Some Special Problems

(JACK E. MCKEE AND THOMAS R. CAMP)

The type and degree of treatment indicated for the wastes from any tannery (or any industrial process, for that matter) are dependent on the requirements of the receiving watercourse. If the wastes are discharged to a municipal sewerage system, pretreatment is usually necessary to protect the sewers and the municipal treatment plant. The methods of treatment are also related to the availability of land, proximity to residences, climate, and similar factors. A small tannery located along a large river or adjacent to the ocean, for example, may require no treatment of its wastes other than effective screening, provided that dispersal and dilution can be effected by properly designed outlet structures. In contrast, a large tannery located near a small stream may be required to effect a high degree of treatment or even refrain entirely from discharging certain wastes directly to the stream, even after treatment. A decision as to the best method of handling wastes from any specific tannery can be made only after a careful study of all governing factors.

Clogging of Screens, Pumps, and Pipelines

Beamhouse wastes contain variable quantities of fleshings, hide shavings, and hair, which tend to mat and clog openings in screens, pumps, and pipelines. When combined with calcium carbonate deposits, such mats will be difficult to dislodge and remove. They may clog the drains within the tannery, the mechanical equipment of treatment works, or municipal sewers into which untreated wastes are discharged.

The most effective remedy for such problems is to reclaim as much of the fleshings, shavings, and hair as possible before they reach the drains of the beamhouse. Such substances have value and can be sold for use in making glue, grease, rug felt, or binders. Even where good housekeeping and effective salvage of coarse material are performed, however, screens are still advisable as a further precautionary measure. For this purpose, bar screens of $\frac{3}{8}$-in. to $\frac{1}{2}$-in. clear spacing should be adequate and mechanical cleaning devices should be installed. Mechanically cleaned bar racks will be less troublesome than revolving or traveling fine screens. Screened material may be salvaged, incinerated, or buried.

High Alkalinity and Hardness

Hides are soaked in solutions of lime and a depilatory agent (such as sodium sulfide) to aid in the removal of hair. Vats containing these solutions are emptied intermittently and the effluent contains a high concentration of dissolved and undissolved lime, sulfide, and breakdown products of the depilatory action. Subsequent washings provide dilution, but also add to the total amount of these substances discharged in the combined wastes. Typical analyses of beamhouse wastes from heavy-leather tanneries show lime contents of 2,000 to 3,000 p.p.m. (expressed as $CaCO_3$), pH values of 11.5 to 12.0, and sulfide contents of 25 to 75 p.p.m. (as S).

The calcium from the lime tends to combine with normal carbonates formed by the reaction of the caustic alkalinity with carbon dioxide dissolved from the air or from products of decomposition to form a precipitate of calcium carbonate. Some of this precipitate can be removed by proper flocculation and sedimentation. Where such wastes are discharged to municipal sewers, however, the calcium should be largely removed by precipi-

tation and settling as calcium carbonate and the remainder should be dissolved with acid or flue gas. Otherwise, calcium will continue to precipitate and deposit in the sewers, thereby necessitating frequent cleaning thereof.

The calcium content of beamhouse wastes may cause an appreciable increase in the hardness of the receiving stream when dilution is low; thus, with a dilution of only 20 to 1 a typical tannery effluent might increase the hardness of the stream by 100 to 150 p.p.m. Generally, however, the B.O.D. would govern the method of handling wastes at such low stream dilutions; and where biological treatment is indicated much of the calcium would be precipitated and removed in the process.

The high pH of wastes from the beamhouse alone or combined with tan liquors will generally preclude biological treatment unless the hydroxide alkalinity is first neutralized with acid or flue gases. The combination of tannery wastes with a large volume of municipal sewage may make such neutralization unnecessary as a prerequisite of biological treatment; but, pretreatment may nevertheless be necessary to protect the sewers from deposits of calcium carbonate.

Sulfides and the Evolution of Hydrogen Sulfide Gas

Sodium sulfide is generally used to "sharpen" or hasten the depilatory action of the lime solution. The sulfide appears to have a catalytic effect in breaking the disulfide linkage in cystine, an amino acid which is the principal component of the keratinaceous substances which form and retain hair on the hides. The chrome tanning of light leathers is generally preceded by larger concentrations of sulfide and shorter liming periods than is the vegetable tanning of heavy leather. Some tanneries use dimethylamine in place of sodium sulfide.

Sulfides are seldom troublesome at the high pH of tannery effluents and if settling tanks are installed to remove excess lime and settleable solids, most of the sulfides will be removed as precipitated CaS. At two heavy-leather tanneries in Pennsylvania, the removal of more than 96 per cent of the sulfides by sedimentation and equalization was observed. In contrast, however, the discharge of unsettled tannery wastes to a sewer or stream may result in a lowering of the pH of the waste to the point where H_2S gas is evolved. Care must be exercised in the use of acid or flue gas in the prevention of $CaCO_3$ deposition to assure that H_2S evolution is not offensive. It is generally wise to remove most of the heavy sludge and sulfides by sedimentation prior to pH adjustment. The sulfide content of the sludge may be troublesome if chemical treatment is used to assist the dewatering of sludge, as explained hereinafter.

Deoxygenation of Receiving Waters

Mixed beamhouse and scrub-house (bleach house) wastes from a typical heavy-leather tannery contain from 500 to 2,000 p.p.m. of 5-day 20° C. B.O.D.; spent vegetable tan liquors will have B.O.D. values of from 10,000 p.p.m. to 45,000 p.p.m. Typical combined beamhouse, scrub-house, and tanyard wastes may be expected to have B.O.D. values of 1,000 to 3,500 p.p.m., much greater than those of normal municipal sewages.

When neutralized and diluted as they are likely to be in a receiving stream, these wastes, jointly or separately, are readily susceptible to biochemical decomposition. The combined wastes present a well-balanced nutrient for many saprophytic bacteria and consequently it is to be expected that in sufficient concentration the wastes will exercise a rapid deoxygenating effect upon receiving waters. The same properties make such wastes amenable to biological treatment un-

der controlled condition, with B.O.D. removals of from 75 to 90 per cent or higher being possible.

Where the diluting water in the receiving stream is not sufficient to prevent excessive deoxygenation by the tannery wastes, remedial action may be taken by the following processes, alone or in various combinations:

1. Flocculation and sedimentation.
2. Chemical precipitation.
3. Biological treatment on trickling filters.
4. Secondary sedimentation.
5. Intermittent sand filtration.
6. Equalization of discharge over a 24-hr. period.
7. Segregation and evaporation of strong wastes (such as tan liquors).
8. Lagooning of strong wastes during periods of critical low stream flow, the wastes to be released when dilution is adequate.

The best method, or combination of methods, for any tannery depends primarily upon the characteristics of the receiving stream.

Discoloration of Receiving Waters

Spent vegetable tan liquors generally contain pyrogallol tannins, catechol tannins, or a mixture of both. When discharged from the tan vats, the liquor has a reddish-brown appearance and in sufficient concentration may impart that discoloration to the stream. If iron is present in the receiving waters, however, the pyrogallol reacts with it to form an inky blue precipitate, whereas catechol forms a dark green precipitate. The iron may also react with free sulfide in unsettled beamhouse wastes to form a black precipitate of ferric sulfide. These precipitates not only grossly discolor the flowing water in the stream, but they also coat the stream bed and banks so that even intermittent discharges of tan liquor at high stages can leave a mark on the stream.

Discoloration is not avoided by biological treatment of tan liquors on trickling filters; in fact, such treatment may possibly accentuate the color.

The problem of discoloration of iron-bearing streams by vegetable tan liquors is difficult of resolution. Chemical precipitation of tan liquors with ferric salts, followed by flocculation, sedimentation, and filtration, might be effective, but it would be expensive. It has been found economical in some tanneries to evaporate and dry the spent tan liquors to produce a marketable product, the income from which can partially defray the expense of handling.

In recent years, synthetic tanning compounds, or syntans as they are called, have shown promise of replacing vegetable tanning materials, most of which have to be imported. It is possible that this development, and other recent strides in research being conducted by the heavy-leather industry, will result in alleviating the problem of discoloration by vegetable tan liquors. Light leather is generally tanned by chrome compounds, which do not exercise a serious discoloring effect. On the other hand, chrome tanning wastes, in sufficient concentration, may be toxic to fish or other aquatic life.

Beamhouse wastes have a greenish-blue milky appearance. Following primary settling and dilution in the receiving stream they seldom impart an offensive discoloration. Scrub-house wastes, which contain dilute tan liquors and thus have a light reddish-brown appearance, can also cause a discoloration of iron-bearing waters.

Dewatering of Tannery Sludge

Primary sedimentation of tannery wastes generally produces a voluminous flocculent sludge, the disposal of which constitutes a major problem in handling tannery wastes. The volume of such sludge will be about 10 per cent

of the total volume of wastes and its solids content will generally be from 2 to 5 per cent, the heavier sludges resulting from excessive amounts of undissolved lime. The sludge contains a high proportion of very fine suspended solids, which together with the precipitated $CaCO_3$ tend to clog the interstices of any filtering medium. The pH value of the sludge, like that of the unsettled wastes, is generally in excess of 11.5 and the methyl-orange alkalinity may be 20,000 p.p.m. or higher. Hence, the sludge is not amenable to digestion by biochemical processes without prior adjustment of pH.

Where adequate land is available, lagooning of the sludge has been found to be a practical and economical method of disposal. Underdrained sand drying beds have been found to be no better than simple lagoons, because the pores in the upper layer of sand are rapidly sealed.

Where adequate area for lagoons cannot be provided, or where esthetic conditions mitigate against their use, sludge can be dewatered partially by centrifuges or by vacuum filters. Centrifuges remove the coarse heavy material in the sludge, but the lighter solids must be returned to the settling tank for further flocculation and sedimentation. This return tends to build up a progressively lighter sludge and adds to the difficulty of centrifuging. Vacuum filtration of unconditioned sludge has been found to be well-nigh impossible, because a very thin coat of fine organic material and calcium carbonate granules quickly plugs the filter cloth. With proper conditioning or with filter aids, however, vacuum filtration is a practical solution to the problem of dewatering sludge in limited areas. Acidification of the sludge to between pH 4 and 5 produces a coarse flocculent material which filters readily, but where sulfides are used in the liming vats provision must be made to dissipate the H_2S which will be released from the acidified sludge. Iron and aluminum salts have been found of little use in conditioning tannery sludge, unless they do so by lowering the pH. In lieu of acid treatment, the addition of filter aids has been found advantageous. For this purpose buffer dust or fine shavings, which are normal waste products in light leather tanneries, have been found useful. If necessary, they may be supplemented by sawdust, although the addition of too much filter aid increases the problem of filter cake disposal.

CORRECTION

In the paper on "Tests and Studies on Air Diffusers for Activated Sludge" (This Journal; April, 1950), the value "211" in the last column, third line of Table V (page 468) should read "112."

TREATMENT OF MEAT PACKING WASTES*

By Leland Bradney, Walter Nelson, and R. E. Bragstad

Superintendent, Sewage Treatment Plant; Mechanical Superintendent, John Morrell and Co.; and City Engineer, respectively, Sioux Falls, S. Dak.

The City of Sioux Falls, S. Dak., has been concerned with the treatment of wastes from the meat packing industry since 1927. In 1909, John Morrell and Company began operation of a packing plant in this city; by 1941 this plant had developed into one of the largest in the country. Before 1927 no treatment problem existed, as both the municipal sewage and the packing plant wastes were discharged directly into the Big Sioux River without treatment.

In 1926, plans were drawn for a treatment plant to handle combined wastes from the meat packing plant and allied industries, as well as the domestic sewage from the City, which at that time had a population of 25,000, 90 per cent of which was sewered. The combined industrial wastes consisted of those from the packinghouse, the local stockyards, and a serum plant. The original treatment plant consisted of primary treatment, standard or low-rate trickling filters, and separate sludge digestion. In 1936, activated sludge treatment facilities were added and designed to treat the combined flow following trickling filter treatment. The operation of the sewage plant up to 1937 has been described in a previous paper (1).

The U. S. Public Health Service (2) has made an extensive study of wastes within packinghouses. This affords a convenient reference which gives the sources and strength of the components of the total wastes discharged by the packing industries. With the exception of strength, these wastes are somewhat similar to domestic sewage, as no toxic products are known to be present. Therefore, these wastes should be amenable to the processes commonly employed for the treatment of domestic sewage. From the experience gained at Sioux Falls, this appears to be essentially true, with the exception that where a high degree of treatment is necessary the relatively high organic nitrogen content poses certain problems, which are discussed later.

In the treatment of such strong wastes as those produced by packinghouses it appears that the first stage of treatment should be within the packinghouse itself, where the strength should be reduced to the lowest possible value by utilization of all feasible salvage operations. It is hoped that further studies will develop methods resulting in greater recovery, at least approaching a break-even point from the standpoint of cost.

Grease Losses

In reporting losses, the desirability of using a unit weight is apparent. For a number of years these losses have been computed on the basis of pounds per 1,000 lb. of live weight of animals killed. This method of reporting losses affords a more desirable value than the hog-unit, which is somewhat elastic. Mohlman (3) suggests reporting losses on a unit weight basis using weight of loss per ton of live weight of animals killed.

* Presented at 22nd Annual Meeting, Federation of Sewage Works Assns.; Boston, Mass.; Oct. 17–20, 1949.

In connection with obtaining values for losses by the meat packing industry the necessity of adequate sampling and accurate flow measurements cannot be over-emphasized. These wastes are relatively high in suspended solids and show considerable variation in both strength and rate of discharge over a 24-hr. period. The use of automatic samplers has proven to be quite satisfactory, and is desirable where feasible. When samplers are not practical the sampling period should not be greater than 15 min. if a reliable sample is to be obtained. It was intended to include herein data covering losses over a period of several years. However, due to unreliable sampling and flow data, false conclusions were indicated (for instance, the data gave an increase in nitrogen losses following installation of additional evaporator capacity).

Of the losses sustained by the packinghouse, those of grease and organic nitrogen appear to be the most objectional if these wastes are discharged to sewers for further treatment by the sewage treatment plant. Excessive grease losses result in scum formation on primary settling tanks and plugging of sludge lines and trickling filter distributors. Furthermore, grease should be considered a by-product, as it has value as a salvaged material. For this reason its recovery should be nearly complete; however, from the available data this appears to be far from the fact. From a survey of 16 packinghouses (including the plant under discussion), Mohlman (3) gives grease losses varying from 0.54 to 12.1 lb. per ton of live weight kill, or a range of nearly 24 to 1. Mortenson (4), in a comprehensive study of grease losses, suggests that the loss of recoverable grease should not exceed 0.1 lb. per 1,000 lb. live weight kill. From the available data, which are assumed to indicate total losses, this value is seldom approached. During the past few years steady improvement has been made in grease recovery at Sioux Falls, having now reached the point where no difficulties are encountered at the sewage treatment plant as a result of such losses. Grease losses are best controlled by the use of adequate catch basins of modern design, incorporating automatic skimming. With modern facilities in operation the grease losses, at best, are seldom less than 4.0 lb. per 1,000 lb. live weight kill; as is general in the industry these losses remain unexplainably high.

Nitrogen

Organic nitrogen, although one of the most undesirable components from the standpoint of sewage treatment, affords one of the best indices for evaluating the strength of packinghouse wastes. The determination of this component utilizes the precision of the Kjeldahl method, affording a more rapid determination and giving results more easily reproducible than by the standard B.O.D. determination. Furthermore, to a considerable degree this method lends itself well to locating abnormal operations. Figure 1 shows organic nitrogen losses during a period of abnormal operation as compared with normal operation.

The excessive discharge of organic nitrogen to a biological treatment unit imposes an unnecessarily high loading and may result in shock loadings, as in many instances the discharge of highly nitrogenous wastes occur periodically and at a high concentration. Furthermore, where dilution requirements are such that a high degree of treatment is necessary to protect the receiving body of water, necessitating two-stage trickling filters and/or activated sludge treatment, high concentration of organic nitrogen is responsible for producing sludges that are extremely difficult to control. Although at the Sioux Falls sewage plant the settled activated sludge in the final tanks is being controlled, the solids from the standard trickling filters have the same

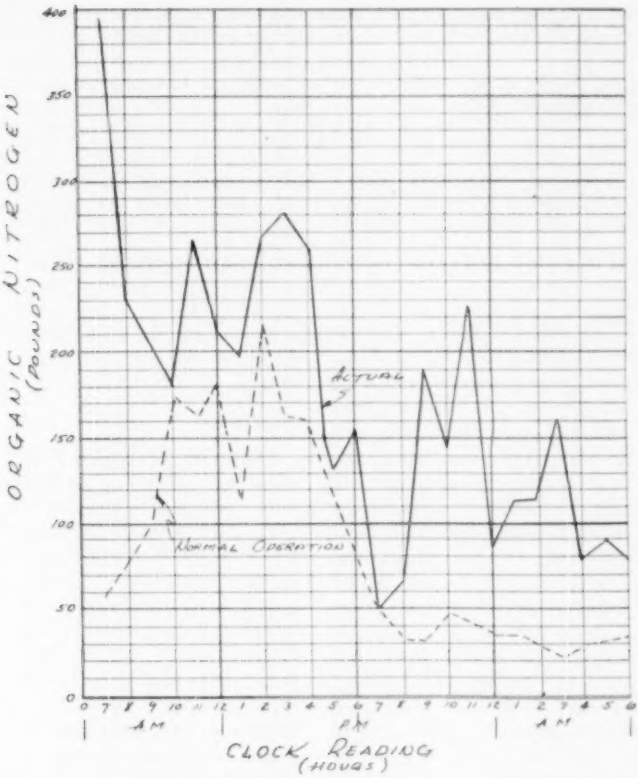

FIGURE 1.—Organic nitrogen losses from packinghouse; 5-day average, in lb. per hr.

tendencies as the activated sludge to rise during the summer months, and most of the sludge removed from the settling tanks following the secondary filters is removed by skimming. In view of the hazards involved in treating high nitrogenous wastes, it is desirable to reduce organic nitrogen losses to the lowest possible value. This requires sufficient evaporator capacity to assure the evaporation of strong nitrogenous liquors during the peak killing periods.

Wastes Plant Operation

Studies indicate that an appreciable reduction of suspended solids as well as some reduction in B.O.D., can be effected by screening paunch manure. Data from 3 days' operation of a 6- by 3-ft. screen having a 70 × 32 mesh are given in Table I. The rate of flow to the screen was 100 to 150 g.p.m. The data show that 74 per cent of the suspended solids and 61 per cent of the B.O.D. were removed from the influent. No clogging of the screen surface was experienced. From the data given in Table I, fine screens offer an economical and practical means of handling paunch manure.

Pretreatment

At present only screening, using a rotary screen having $\frac{1}{8}$-in. openings, is in use. Degritting facilities are be-

TABLE I.—Effectiveness of Paunch Manure Screening at Flows of 100 to 150 G.P.M.

Date July, 1945	Operation Period (hr.)	Total Recovery (lb./hr.)	Dry Solids (%)	Dry Solids Recovered (lb.)			Susp. Solids (p.p.m.)			B.O.D. (p.p.m.)		
				Per Hr.	Total	Per 1,000 lb. Live Weight	Infl.	Eff.	% Red.	Infl.	Eff.	% Red.
17	7.25	2,260	10.2	265	1,923	7.82	3,530	1,750	50.0	—	—	—
19	8.25	2,573	14.7	378	3,118	12.37	8,050	1,380	82.8	1,160	480	58.6
23	7.25	2,804	10.5	294	2,134	9.74	11,580	1,290	88.8	1,280	460	64.0
Av.	7.58	2,545	11.8	312	2,391	9.97	7,720	1,473	73.9	1,220	470	61.3

ing provided ahead of the new pumping station handling the packinghouse waste for the purpose of reducing wear in the pumps. In the past some $90,000 has been expended for presettling of the waste and sludge removal. For a number of years the sludge from the presettling tanks was filtered; later a centrifuge was used, then abandoned, and an effort was made to pump the sludge to the digesters at the sewage treatment plant. It proved very difficult to pump the sludge through the 800-ft. long line. Furthermore, no appreciable advantage was gained from dual settling of the waste; consequently, pretreatment has since been limited to grease removal, screening, and degritting.

Primary Settling

When grease losses are kept to a reasonably low value and suitable screening is provided ahead of the sedimentation tanks, no difficulties have been experienced in the settling of the waste. During periods of excessive grease losses considerable trouble was experienced from excessive scum load, plugged sludge lines, and distributor clogging. Unless proper screening is provided sludge removal by sludge pumps is almost impossible, due to the matting effect from the straw contained in the paunch manure.

The clarifier is operated at overflow rates varying from 600 to 1,300 g.p.d. per sq. ft. At these rates 60 to 70 per cent of the suspended solids and 45 to 50 per cent of the B.O.D. is removed.

Digestion

Digestion of packing plant wastes offers no particular problems if suitable means are provided to control scum formation in the digestion tanks. Prior to the installation of mixing devices, excessive scum resulted in the digester roof being lifted due to sealing of the gas vents and overflows. Each 85-ft. diameter digester has been provided with two mixers, the performance of which has been quite satisfactory. The digestion of grease is nearly complete; during a period of high grease losses by the packinghouse the raw packing plant sludge contained 48 per cent petroleum ether extract (dry solids) and was reduced by digestion to 3.0 per cent, a reduction of 94 per cent. Loadings vary from 2.0 to 3.2 lb. of volatile solids per cubic foot of digester capacity per month, with an average gas production of 8.0 cu. ft. per lb. of volatile applied.

Trickling Filters

Prior to 1942, due partially to increased load on the plant, the final effluent had deteriorated to the point that required provision of additional treatment facilities to prevent serious pollution of the Big Sioux River and the recurrence of law suits by the riparian owners and tenants along the river below the treatment plant. In

the preceding years the City had paid some $120,000 as a result of such law suits. Among factors aggravating this condition was the failure of the standard filters to perform efficiently in the cold months, putting an excessive load on the activated sludge plant at the most critical time of the year; that is, when packing plant operations were at their peak, and the river flow at its lowest stage. In order to improve the performance of the standard filter it was decided to make sweeping improvements, as follows:

1. Primary trickling filters, of the backwash type, having a maximum designed loading of 8,000 lb. B.O.D. per acre-ft. were installed ahead of the standard filters. Facilities were provided for settling the effluent from these filters, whose operation has since been quite satisfactory, even during the war years when loadings approached 15,000 lb. per acre-ft. for several consecutive days during the heavy killing periods. The periodic ponding was controlled by the backwash facilities.

2. The original standard filters had an area of 4 acres and were equipped with dosing siphons and fixed nozzles. The siphons were eliminated, the fixed nozzles being replaced by rotary distributors. It was felt that better utilization of the filters would be afforded by the rotary distributors, even in view of the fact that some 25 per cent of the filter area would be lost.

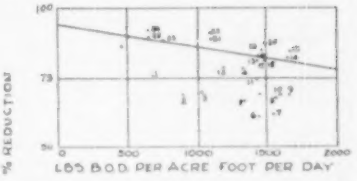

FIGURE 2.—Performance of primary filters during period Nov. 1943 through April 1944.

3. Provision was made for recirculation at a rate of 5.0 m.g.d. Facilities for settling this portion of the secondary filter effluent were available. Performance of the primary filters for the period Nov., 1943, through April, 1944, is shown in Figure 2. During this period the filters performed well, with a loading in excess of 12,000 lb. B.O.D. per acre-ft. for a considerable part of the period covered by the curve. Figure 3 shows the removal and loading on the standard trickling filters for the same period. Table II gives data for the year 1947, including nitrification.

TABLE II.—Performance of Secondary Filters during 1947

Month	Flow (m.g.d.)	B.O.D.			Deduction (%)	Oxidized Nitrogen	
		Infl. (p.p.m.)	Applied (lb./ac.-ft.)	Effl. (p.p.m.)		NO_2-N	NO_3-N
Jan.	4.560	529	1085	131	75.2	.65	3.29
Feb.	4.368	334	661	66	79.7	1.54	3.98
Mar.	4.332	260	510	46	82.6	1.87	11.70
Apr.	4.650	196	412	55	71.9	3.17	14.10
May	4.561	225	474	34	85.0	3.33	15.60
June	4.386	198	392	41	79.3	1.29	9.30
July	4.329	191	374	40	79.0	1.06	8.20
Aug.	4.229	202	386	41	79.8	.94	9.00
Sept.	4.260	204	394	40	80.4	.81	5.10
Oct.	4.420	298	597	46	84.6	.54	2.80
Nov.	4.689	368	780	122	71.8	.96	3.20
Dec.	4.651	373	786	121	72.3	.85	2.60
Av.	4.452	281	570	65.2	76.8	1.41	7.40

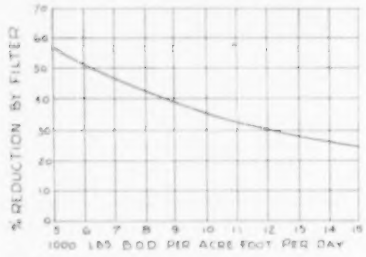

FIGURE 3.—Performance of secondary filters during period Nov. 1943 through April 1944.

By comparing these data with 1942 shown in Figure 4 considerable improvement in performance of the standard filters will be noted.

Rising Sludge Problem

Nitrification by the waste treatment plant filters aggravated the problem that has been present at this plant since the installation of an activated sludge process; namely, the rising of activated sludge in the final sedimentation tanks. Sawyer and Bradney (5) studied the rising or floating of activated sludge in final sedimentation tanks, demonstrated by O'Shaughnessy and Hewitt (6) to be caused by the buoying of the sludge due to the entrainment of nitrogen gas. There is some difference of opinion regarding the mechanics of the process, although there is general agreement that nitrite and/or nitrate must be present. Wooldridge and Corbet (7) attribute the cause to biological denitrification of oxidized nitrogen; this is supported by the evidence obtained from the Sioux Falls studies.

The only detrimental effect from the rising sludge phenomenon appears to be the contamination of the final effluent with mixed liquor solids, the capacity of the sludge to purify sewage not being impaired. Bulking sludge has been a rare occurrence; the sludge index seldom exceeds 200 and 100 is more nearly normal. As no practical means have been found to sufficiently

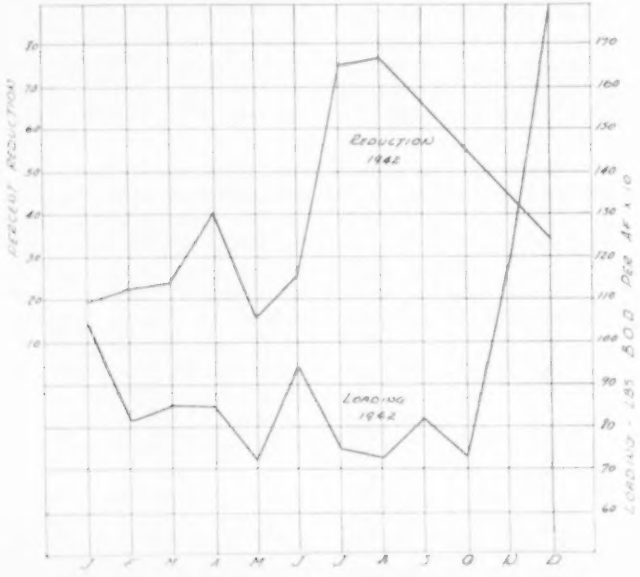

FIGURE 4.—Performance of secondary filters during 1942.

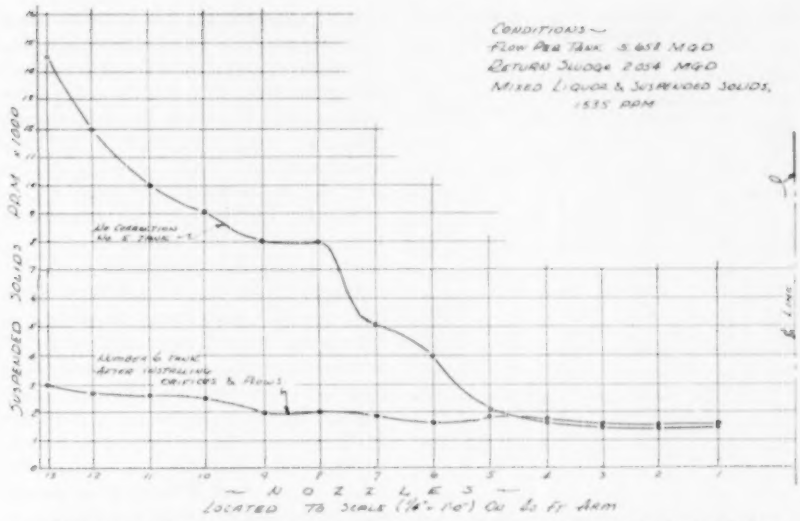
CONDITIONS —
FLOW PER TANK 5.658 MGD
RETURN SLUDGE 2.054 MGD
MIXED LIQUOR & SUSPENDED SOLIDS, 1535 PPM
SUSPENDED SOLIDS PPM x 1000
NO CORRECTION ON 6 TANK
NUMBER 6 TANK AFTER INSTALLING ORIFICES & FLOWS
— NOZZLES —
LOCATED TO SCALE (76° - 10°) ON 20 FT ARM

FIGURE 5.—Effect of collector installation on sludge concentration in final clarifiers.

retard the rising of the sludge, it was decided to attempt to control it by removal from the final sedimentation tanks before it had sufficient time to become buoyant. Studies by Bradney and Sawyer (8) during a winter period when no appreciable nitrification was present show that a considerable portion of the sludge remained in the tanks in excess of 3 hr.; an impossible condition if rapid removal was to be accomplished. The rate of return sludge was found to be adequate (40 to 50 per cent), but the return sludge was quite low in solids (4,000 to 7,000 p.p.m.) although at the same time the sludge at the outer areas of the tank showed a suspended solids concentration as high as 14,000 p.p.m., indicating ineffective sludge removal.

Study of suction-type sludge removal equipment seemed to offer a reasonable possibility of relief, as it was believed that this equipment would remove the sludge more rapidly. Consequently, suction-type sludge removal mechanisms were installed in both final sedimentation tanks, which are 80 ft. in diameter and 9 ft. deep. These mechanisms were put in service in November, 1945. Samples were taken from the bottom of the tanks near the center of the path of the nozzles and just after the nozzles had passed the sampling points. The samples revealed that the sludge was not being removed from the outer areas of the tanks at a sufficiently rapid rate to prevent rising. The suspended solids concentration at each nozzle is shown in Figure 5. Anderson (9) discovered in final sedimentation tanks density currents which appeared to be responsible for the failure to obtain an even distribution of sludge over the entire area of the tank. Velocity tests on the Sioux Falls tanks bear this out, indicating excessive bottom velocities up to the fifth nozzle. Furthermore, samples collected from this area showed no appreciable increase in suspended solids concentration when the first 5 nozzles were blanked off. The condition is shown in Figure 5 for the case of No. 6 tank, on which the first five nozzles were closed as compared with No. 5 tank, where all nozzles were open. The possibility that these velocities

TABLE III.—Pipe and Orifice Areas (for 1 Arm Only; Nozzles Numbered from Tank Center)

Nozzle No.	Computed Size and Pipe Area		Area of Ring (sq. ft.)	Present Orifices	
	Diam. (in.)	Area (sq. in.)		Diam. (in.)	Area (sq. in.)
1	2	3.14	27.7	—	—
2	2	3.14	103.0	—	—
3	2½	4.908	160.0	—	—
4	3	7.068	216.0	—	—
5	3½	8.295	273.0	—	—
6	3½	9.621	330.0	3	7.060
7	3½	11.045	386.0	2½	4.908
8	3½	11.045	443.0	3	7.068
9	4¼	13.36	500.0	3½	8.295
10	4 13/16	17.25	556.0	3½	11.045
11	5 3/16	21.38	612.0	4	12.50
12	5 3/16	21.38	669.0	4¼	18.0
13	5¼	23.75	725.0	5¼	23.75

might cause difficulty was taken into consideration in the design of the mechanisms, provision being made for inserting orifices in the pipes leading from the nozzles to the header. By changing the area of the inlets a reasonably good removal of sludge from the outer area of the tanks was possible without increasing the concentration of suspended solids in other areas (see Figure 5). It was then felt that the rising sludge problem was indeed under control, at least, to a considerable extent. However, in the following May the rising of sludge in the final sedimentation tanks as usual announced the arrival of Spring.

Further studies indicated that nozzles were removing the sludge directly in their paths, the sludge between the nozzles flowing in behind them after they passed. As a result, a portion of the sludge moved back and forth between the nozzles, with the result that part of the sludge remained long enough to reach buoyancy. Addition of V-type plows between the nozzles corrected this condition, the suspended solids in the final effluent dropping to and remaining below 20 p.p.m.

Furthermore, the mixed liquor solids could be maintained at the desired level. Figure 5 shows the concentration of the sludge in the bottoms of the tanks with No. 5 tank operating without plows and no correction in inlet areas, whereas on No. 6 the plows are installed and orifice areas are as

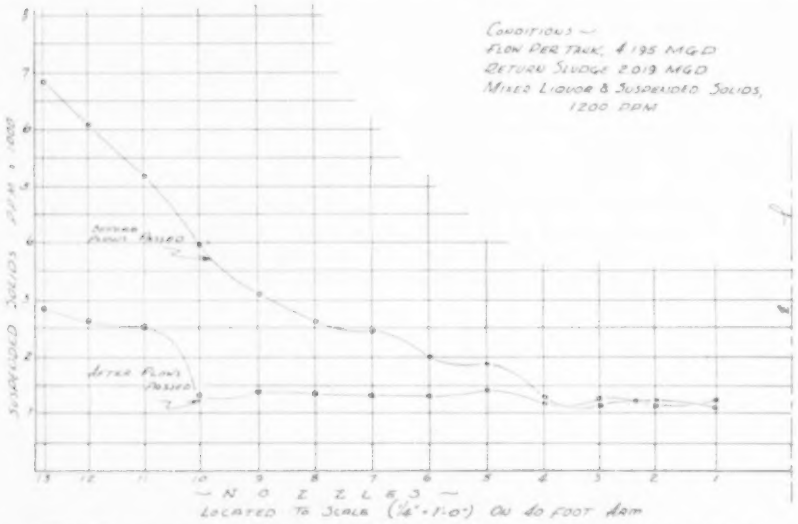

FIGURE 6.—Effect of collector passage on sludge concentration in final clarifiers.

shown in Table III, which gives a comparison of the areas originally computed and the ones which have proven to be more effective. Figure 6 shows the sludge concentration before and after the collector mechanism passed the sampling points, after corrective orifices and plows were installed.

Domestic Sewage

At Sioux Falls the treatment of domestic sewage is only incidental to that of the major problem of treating the industrial wastes. The domestic sewage serves as a highly desirable dilutant, the volume of which on the average is equal to that of the industrial waste. The treatment afforded the domestic sewage has been described previously (5).

Monthly averages of B.O.D. and suspended solids in the final effluent for the years 1942, 1944 and 1947 are given in Table IV. The year 1942 might serve as a starting point, being the year just prior to the rehabilitation of the standard trickling filters. It is noted that during this period the quality of the final effluent was rather poor, which is attributed to excessive loading of the aeration tanks resulting from the poor performance of the standard filters. It was during this period that the loading on the aeration tanks approached 100 lb. B.O.D. per 1,000 sq. ft. of tank capacity. The aeration tanks have performed well since, with loading up to 50 lb. B.O.D. per sq. ft., requiring from 750 to 800 cu. ft. of air per lb. of B.O.D. removed in the absence of rising sludge. During the 13 years that these tanks have been operating no difficulty has been experienced with clogging of plates. Comparison of the final effluents obtained in 1944 with those of 1942 shows a considerable improvement during the winter months. However, a definite deterioration of the final effluent during the summer months is apparent. This was no doubt the result of aggravation of the rising sludge problem due to increased nitrification by the standard filters.

TABLE IV.—Monthly Averages of Final Effluent B.O.D. and Suspended Solids

Month	Suspended Solids (p.p.m.)			B.O.D. (p.p.m.)		
	1942	1944	1947	1942	1944	1947
Jan.	132.0	58	19.0	164.0	69.0	20.0
Feb.	97.0	66	18.0	100.0	77.0	13.0
March	88.0	25	11.1	67.5	62.0	9.6
April	31.5	83	11.1	37.7	53.0	12.0
May	29.6	56	13.0	37.0	52.4	13.0
June	23.0	60	13.5	52.0	61.0	9.2
July	28.5	62	11.7	37.5	67.0	8.2
Aug.	24.0	68	12.0	37.0	54.0	11.0
Sept.	37.0	42	13.0	37.0	56.0	11.0
Oct.	54.0	56	11.8	73.9	61.0	11.9
Nov.	75.0	34	12.0	89.0	53.0	13.8
Dec.	140.0	33	13.8	243.0	31.0	16.0
Av.	63.2	53.5	13.3	81.3	58.0	12.3

1947 was the first full year of operation following the installation of the suction-type sludge removal mechanisms as modified. Consistently good removals of suspended solids and B.O.D. are shown for the year. The improvement during the summer months can be accounted for by the more rapid removal of sludge from the final clarifiers. However, the appreciable improvement of the final effluent during the winter months, at which time rising sludge is not critical, must be attributed to some other factor.

Concurrent with the reduction of suspended solids and B.O.D. in the final effluent during the winter months, new grease removal facilities were put into operation, along with the removal of certain highly concentrated nitrogenous wastes as a result of increased evaporator capacity. Prior to this time the nitrogenous wastes were only discharged during the period of heavy killing operations at the packinghouse, which coincides with the winter months. It is to this factor that the improvement of the final effluent during the winter months is substantially

attributed, not overlooking the deleterious effects on the treatment processes resulting from the discharge of the nitrogenous wastes. Re-emphasis should be placed on the necessity of reducing the strength of the waste within the packinghouse whenever and wherever practical; successful treatment by the sewage plant may be dependent on the vigilance exercised at this point.

Conclusions

As a result of the studies and operations reported herein, the following general conclusions may be drawn:

1. The present proven processes for treating domestic sewage are applicable to treating packinghouse waste, although certain modifications are indicated.

2. Treatment of wastes begins within the packinghouse.

3. Rapid and complete removal of activated sludge from final settling tanks is of paramount importance.

Acknowledgments

The authors wish to express appreciation to C. I. Sall and A. R. Olson of John Morrell and Co. for making data available; to K. V. Hill of Greeley and Hansen for preparing the loading curves on the filters; and to B. T. Yeager, Commissioner, City of Sioux Falls, for his cooperation.

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DISCUSSION

By Clair N. Sawyer

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The wastes produced in the meat packing industry stand fourth on the list of "River and Stream Enemies." The total volume of such wastes approximates 300 m.g.d., with a population equivalent of 13,000,000 people on a B.O.D. basis. Due to seasonal peaks, these values may double for periods of several weeks at a time.

The intensity of the problem created by meat packing wastes is a result of numerous factors, the major ones being quantity of waste and volume of receiving water. Consequently, the problems encountered vary widely.

The paper presented by the authors relates the story of how engineers, sanitary chemists, and biologists have joined forces to solve the problems caused by meat packing wastes at Sioux Falls. They are to be congratulated on their accomplishments and

their willingness to keep the profession informed.

In reviewing the paper by Messrs. Bradney, Nelson, and Bragstad, it appears that there are three very important considerations that need amplification, as follows:

1. Information on normal losses is of tremendous importance in providing goals of attainment.

2. Limiting B.O.D. removals by high-rate filters treating meat packing wastes may be somewhat lower than for similar filters treating domestic wastes.

3. Even though the functional design of a treatment plant may be correct, the plant may fail to do the work expected because of faulty mechanical equipment or analytical methods which give false results.

Losses at Sioux Falls

The following table summarizes the losses at Sioux Falls during 1945 and during 1947–48 after a campaign had been carried on to reduce losses. The data are compared to those reported by Mohlman (1) for 14 plants in Chicago. It will be noted that organic nitrogen losses have been reduced to what might be termed reasonable figures, due, no doubt, to the installation of evaporation facilities to handle all stick liquor during peak kills.

Grease losses have been materially reduced, but remain about four times greater than they should be, based on Chicago experience. This would appear to reflect on salvage operations within the plant, particularly in the rendering department. The high content of saponified grease (in excess of 7.2 lb. per ton of kill) must be due to some unusual situation in the processing of fatty materials. Improper preservation prior to rendering will allow souring of the fat and production of free acids which are not recoverable by conventional flotation methods. Due to the nature of the water supply at Sioux Falls (hardness in excess of 500 p.p.m.) a considerable part of the saponified fats precipitates as calcium and magnesium salts in the grease separation unit. A critical study of the overflow liquor and the sludge produced in these units should give some real clues to methods of further reducing the losses.

Losses at Sioux Falls and Chicago (in Lb. per Ton Live Weight Killed)

Loss	Sioux Falls		Chicago[1]	
	1945	1947–48	Av.	Range
Organic N	4.7	3.30	3.5[2]	1.6–5.3[2]
Susp. Sol.	29.0	41.0	22.7	9.1–44.3
B.O.D.	47.3	38.3	28.9	13.0–41.5
Grease	19.8	11.4	2.6	0.5–5.7

[1] Results from 14 plants.
[2] Total nitrogen; approximately 80 per cent organic N.

B.O.D. losses are considerably higher than the average for the Chicago plants. No doubt, this is due mainly to high grease losses and, as soon as grease losses are reduced to normal, it would appear that B.O.D. losses would also adjust themselves accordingly. Each pound of grease exerts a 5-day B.O.D. of about 2 lb.; therefore, a reduction in grease of 8 lb. would reduce the B.O.D. by 16 lb., giving a B.O.D. loss of about 22 lb., or well below the Chicago average.

Although suspended solids losses are abnormal, it does not appear that they materially affect the B.O.D. losses. However, attention should be directed to reducing these losses within the packing plant, in particular the fine screens used for salvaging paunch manure. The suspended solids would appear to have an unusually high content of inorganic matter, but no data is readily available to support such a contention.

B.O.D. Removals on High-Rate Filters

Considerable information has been accumulated during the past few years to show the limiting capacity of high-

rate filters to remove B.O.D. The paper under discussion adds to these data. Summary data from the Upper Mississippi Report, the NRC Report and the Sioux Falls studies are shown in Figure 1. The upper Mississippi and Sioux Falls data show that, for loadings in excess of 9,000 lb. of B.O.D. per acre-ft., B.O.D. removals are quite constant. The NRC data indicate that the leveling-off point is at about 5,000 lb.

There is considerable variation in what the limiting removals are. The Upper Mississippi Report indicates about 5.2 lb., the NRC report 4.3 lb., and the Sioux Falls data 3.5 lb. The low values at Sioux Falls could conceivably be related to the nitrogenous character of the wastes. Another factor that should not be overlooked in this consideration is rock size or biological surface exposure. The rocks in the primary filters at Sioux Falls are of large size (2½ to 4½ in.) and would give less biological surface. Another factor would seem worth mentioning—that the filters at Sioux Falls are of the backwash type and periodically the biological growths are flushed off. Conceivably, some interruption in B.O.D. removal could result and, therefore, lower values. Thus, it would seem desirable to tag the Sioux Falls data as pertinent to filters of the backwash type.

Failure of Mechanical Equipment to Perform Its Job

The Sioux Falls story would not be complete without a chapter showing how the best-laid functional plans of the designing engineer can be fouled up by faulty mechanical equipment. Figure 2 shows the behavior of the plant in 1942. It will be noted that results were terrible during the winter months, but fairly good from April through September. Following extensive additions and alterations to the plant in 1943, the new plant was placed in operation and the results accomplished are shown by the 1944 data. These data show that although the effluent produced during the winter was much improved, a deterioration in the quality of the effluent occurred during the months of May through September. This was correlated with the rising of activated sludge and its overflow in the final clarifiers.

Following extensive studies, in which plant operation was varied, laboratory investigations made, and the behavior of the final clarifier mechanisms examined, it was concluded that

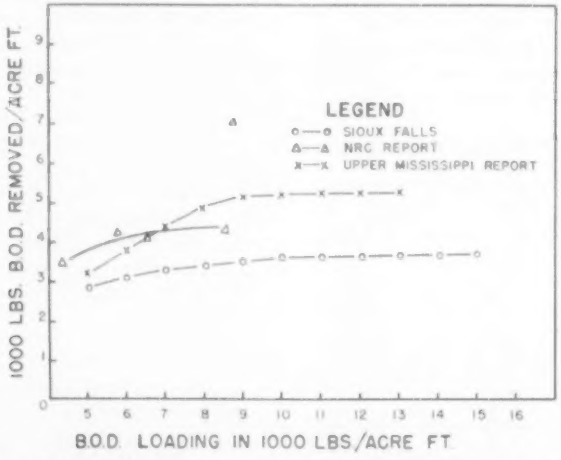

FIGURE 1.—Relationship between B.O.D. removals and loadings on high-rate filters.

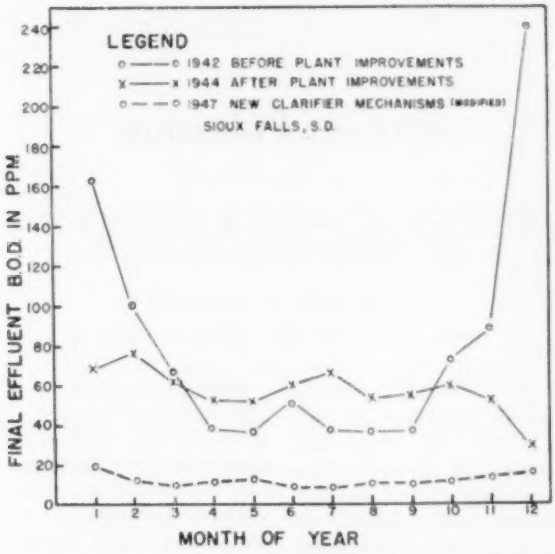

FIGURE 2.—Effect of replacement and improvement of final clarifier mechanisms on plant operation.

replacement of the final clarifier mechanisms with a type capable of removing the sludge more rapidly would solve the problem. Replacement of the mechanisms helped to alleviate the problem of rising sludge, but did not solve it until certain modifications were made in design. The results obtained in 1947, following improvements in design, also are shown in Figure 2.

It seems pertinent to point out that clarifier mechanisms of the 3 basic types used in circular tanks have been used at Sioux Falls. None of them as originally installed would handle the sludge during the summer months. The first two types tried were of a design which seemed hopeless from the standpoint of modification to enable them to do the job required of them. The third type offered such promise and the gamble taken by the city officials in advancing funds for their purchase has been amply compensated by solution of this problem. Furthermore, the designing engineer has been enjoying life a bit more.

The lesson to be learned here is that the best-laid plans go astray unless particular attention is paid to many details. In particular, clarifier mechanism manufacturers should arm themselves with a knowledge of density currents, discard the conventional hydraulic handbooks, and study the movement of sludges, not water.

In addition, the Sioux Falls story illustrates the great need for combined and cooperative efforts on the part of sanitary engineers, chemists, and biologists for whipping into line some of our great industrial waste problems. Special mention should be made of the work of Dr. Mohlman and Mr. Warrick in providing yardsticks of losses for the meat packing and paper industries. Their example should set a pattern for all to follow.

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Stream Pollution

THE ADDITION OF SODIUM NITRATE TO THE ANDROSCOGGIN RIVER *

By Walter A. Lawrance

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From June 15 to October 1, control of the industrial pollution of the Androscoggin River, by court authority, is vested in an administrator. The objectives of this control are the maximum economic industrial use of the water and to prevent the emanation of odor at nuisance levels in the twin cities of Lewiston and Auburn, Maine.

The sulfite pollution load may be controlled by the administrator by one or all of three methods:

1. Sulfite pulp production in two mills may be decreased within certain limits based on river flow and temperature conditions downstream (1).
2. The volume of strong sulfite waste liquor lagooned at a third mill may be varied within certain limits.
3. Sodium nitrate, up to 1,000 tons, may be used to reduce or prevent the formation of hydrogen sulfide in the Androscoggin Pool.

Although the first two of these methods are beyond the scope of this paper, they are an important part of the system of control. However, the addition of sodium nitrate to the river made possible the production of more sulfite pulp than would have been permitted otherwise.

Three companies produce sulfite pulp in the Androscoggin River Valley, the mills being located 112, 59, and 32 river miles from Lewiston. During the summer, the strong sulfite liquor produced at the mill nearest Lewiston is discharged into a lagoon built jointly by the three paper companies.

Location of the Androscoggin and Deer Rips Pools

The Androscoggin pool is a body of water extending northward from Gulf Island Dam to North Turner Bridge, a distance of 14 mi. Turner Center Bridge is nearly equidistant between these two locations. The northern half is comparatively narrow, less than 500 ft. wide in most areas, and contains about 20 per cent of the water in the pool. For about 3 mi., the southern portion of the pool is somewhat wider and then suddenly extends irregularly to ½ to 1 mi. in width, due to existence of several bays. Owing to contours, and the presence of brooks and springs, the pollution load in the bays may be less than that in the channel.

As indicated in Figure 1, the depth of the pool gradually increases. Then about 2½ mi. north of the dam, a rapid decline occurs to about 65 ft. In the channel of the old river, a few depths of 70 and 75 ft. have been recorded. The time of passage (2) through this pool is about 10 days at 2,000 c.f.s.;

* Presented at 22nd Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; October 17–20, 1949.

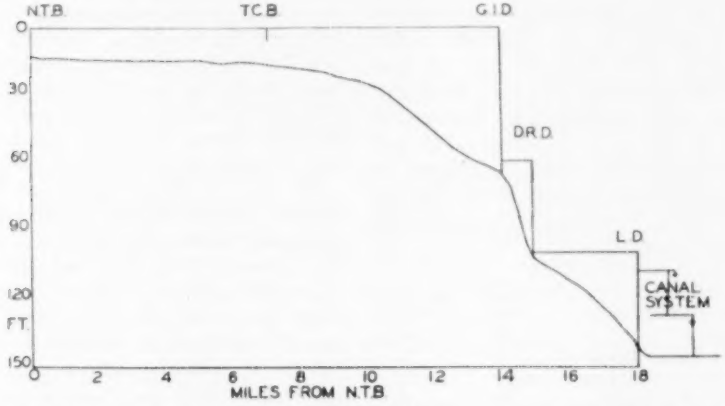

FIGURE 1.—Profile of Androscoggin pool, river, and canals, Lewiston, Me.

this long period of detention is a principal factor in the odor problem.

Located about 1 mi. south of Gulf Island Dam is Deer Rips Dam, which retains a pool known by the same name. At normal summer flows, the time of passage through this pool is 24 to 30 hr. Downstream another 3 mi. are the Lewiston Dam and the gatehouse to the canal system. The river, upper, and lower canals are located near the industrial and population centers of Lewiston and Auburn.

Theory

The use of sodium nitrate to maintain an environment favorable to aerobic bacteria and to avoid the odors produced under anaerobic conditions has been known and used for a long time. In recent years it has been employed on a larger scale for these purposes (3). The pioneer work of Sanborn (4) has led to the extensive use of the addition of sodium nitrate to cannery wastes before discharge into lagoons. More recently, sodium nitrate has been used to suppress the formation of hydrogen sulfide in sewers in a California community.

Oxygen present in sodium nitrate is available to bacteria when the dissolved oxygen in the water has been or is about to be exhausted.

The use of nitrate nitrogen as a proton acceptor must be accompanied by a definite series of oxidation-reduction potentials and although some of the redox processes of microorganisms are obscure, the sign of the potentials which must exist for the utilization of some sources of oxygen has been established. These may be arranged in the following order:

+Dissolved oxygen +Nitrate +Nitrite	Aerobic Range
−Sulfate −Phosphate	Anaerobic Range

This does not imply that a well-defined demarcation exists—conditions are too complex for that—but it does mean that water containing available nitrate, but devoid of dissolved oxygen, should not be considered as anaerobic.

One of the advantages obtained by the use of nitrate is that, during its reduction by micro-organisms, the potential maintained is in a region much above the − 200 to − 300 m.v. which Starkey (5) states is the range in which *Sporovibrio desulfuricans* produces hydrogen sulfide from sulfates.

1948 Program

During the summer of 1948, the abnormally low precipitation, accompan-

ied by high temperatures, produced odor conditions in the river which were at times objectionable. A hurried decision was then made to experiment with the large-scale addition of sodium nitrate to the water. The first applications were made on August 10 and the last on September 23. During this period, 480 tons of nitrate were used as follows:

Location	Amount Used (Tons)	Number of Days
Chisholm	62	10
North Turner Bridge	3	1
Turner Center Bridge	399	35
Pool S. of T. C. B.	16	6

Owing to intermittent and uncertain deliveries, the deposition of nitrate in the river frequently could not be made either at the time or in the quantity that conditions would appear to require.

The experience gained during the summer of 1948 may be summarized as follows:

1. Sodium nitrate was consumed in the areas where the water was devoid of oxygen, the reduction product being principally ammonia.

2. The fixed location of the place of addition, Turner Center Bridge, which is about 8 days flow distant from Lewiston, made very difficult the economical use of the sodium nitrate.

3. Reduction of the amount of hydrogen sulfide in the water was encouraging.

1949 Program

The results obtained in 1948 appeared to justify repetition of the experiment in 1949 on a somewhat larger scale. The administrator set as the objective of this program the addition of sodium nitrate in such amounts as to prevent the presence of hydrogen sulfide in any amount that would produce a nuisance odor from the water in the canal systems located in the center of the two cities. For this purpose 1,000 tons of sodium nitrate were made available, but owing to an unexpected reduction in sulfite pulp production during July, only 641.5 tons were actually used.

To avoid the disadvantages of a fixed location of deposition, a substantial boat was purchased. A 5-ton load, consisting of 100 bags of nitrate, was the usual amount deposited during a single run, and three loads were generally discharged in an 8-hr. period. Of the 641.5 tons of nitrate added to the water, 561.5 tons were deposited from the boat in the southern half of the pool.

The amount of sodium nitrate to be used each day and the location of its addition were based on:

1. Water temperatures.
2. Industrial pollution load.
3. Dissolved oxygen content of the water.
4. Oxygen consumed from permanganate.
5. Methylene blue stabilities.
6. Odor conditions.
7. Prior treatment upstream, if any.

Determinations of 5-day B.O.D. were made each Thursday and at such other times as were necessary. The time which must elapse before the results of the test are available preclude its use as a daily control method. Much shorter periods of incubation often yielded unreliable data.

For the purpose of averaging and comparing data from each of the three principal sampling stations in the pool, two periods were chosen for each location and corrected for time of passage in order that the analytical data being compared would be that from practically the same water. The short June and September periods contain marked variables in flow or temperature and are not included here.

July period	North Turner Bridge	July 1 to July 31
	Turner Center Bridge	July 3 to Aug. 2
	Gulf Island Dam	July 11 to Aug. 10
August period	North Turner Bridge	Aug. 1 to Aug. 31
	Turner Center Bridge	Aug. 3 to Sept. 2
	Gulf Island Dam	Aug. 11 to Sept. 10

Numerous locations throughout the southern portion of the pond were sampled daily or very frequently for analysis, but the data obtained are too extensive for inclusion herein. For the most part they furnish the gradients which existed between Turner Center Bridge and Gulf Island Dam.

Water Temperatures

The temperature of the water in the Androscoggin pool through June was unusually high; 20° C. was recorded on June 5, the earliest date in many years. Higher than normal temperatures existed until after September 10 (see Table I).

In the early part of the summer, water entering the pond is warmer than that leaving; a reverse situation exists during late summer. However, a cold summer night, by no means uncommon in Maine, may lower the temperature of the incoming water by two or more degrees and this cooler water may eventually force deep anaerobic water up toward the surface.

In the Androscoggin river and pool, temperature is one of the most important factors in the present pollution situation. At 19° C. acceptable conditions usually prevail, whereas at 24° C. and higher undesirable developments may proceed very rapidly, due to the fact that micro-organisms are very susceptible to thermal changes in their environment and may double their rate of activity with an increase of 7° to 10° C.

TABLE I.—Weekly Average Water Temperatures at Gulf Island Dam (1949)

Week Ending	Temp. (°C.)	Week Ending	Temp. (°C.)
June 5	16.9	July 31	24.3
12	19.9		
19	22.6	Aug. 7	26.2
26	23.8	14	26.0
		21	24.1
July 3	21.3	28	22.4
10	24.5		
14	23.4	Sept. 4	22.1
24	24.3	11	21.4
		18	19.5

River Flow

The flow from the upland storage water in lakes and reservoirs is rigidly controlled (for example, see Figure 2, Berlin, N. H.). Although the uncontrolled runoff downstream from Berlin, N. H., may at times be very large, the precipitation during the summer of 1949 was so small and the ground so dry that only one short period of abnormal high runoff occurred.

Figure 3 contains an excellent illustration of the marked difference which may exist between the hydraulic crest and the time of passage of water molecules. The peak of the flow which was at Rumford, Maine, June 22, was recorded at Gulf Island Dam on June 23, but the water from Rumford on that date did not arrive at the dam until about a week later.

Industrial Pollution Load

Pollution loads in the Androscoggin River are calculated on a basis which includes the time of passage from their source to Gulf Island Dam. The wide variations in load (Figure 3) were principally the result of week-end shut downs. Midsummer production was lower than normal for about 4 weeks.

Pollution factors are calculated from the compensated tonnage of sulfite pulp produced per 1,000,000 cu. ft. of water passing Gulf Island Dam. The average factor for the 1949 control

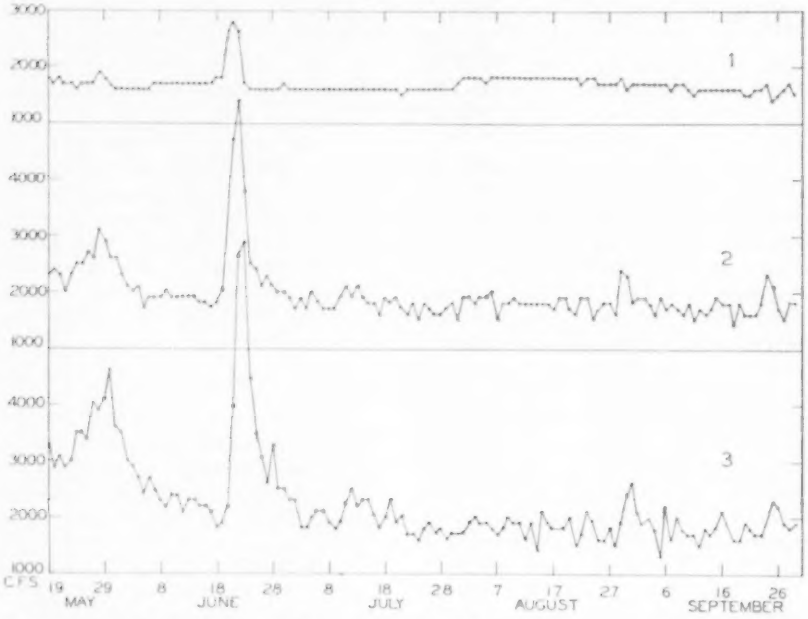

FIGURE 2.—River flow at: (1) Berlin, N. H. (2) Rumford, Me. (3) Gulf Island Dam.

period was 1.9, and for 1948, 2.0. The factors for similar periods prior to control, were: 1947, 2.0; 1946, 2.4; and 1945, 2.1.

Dissolved Oxygen

Determinations of the dissolved oxygen content of river water sampled at a depth of 10 ft. were made each day

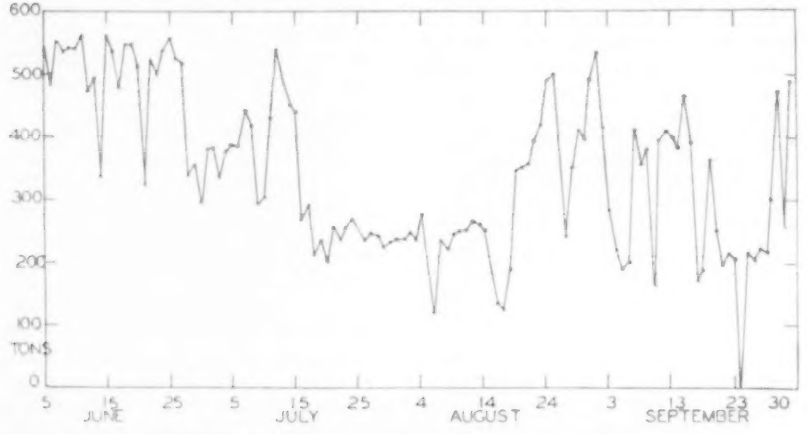

FIGURE 3.—Compensated sulfite production load.

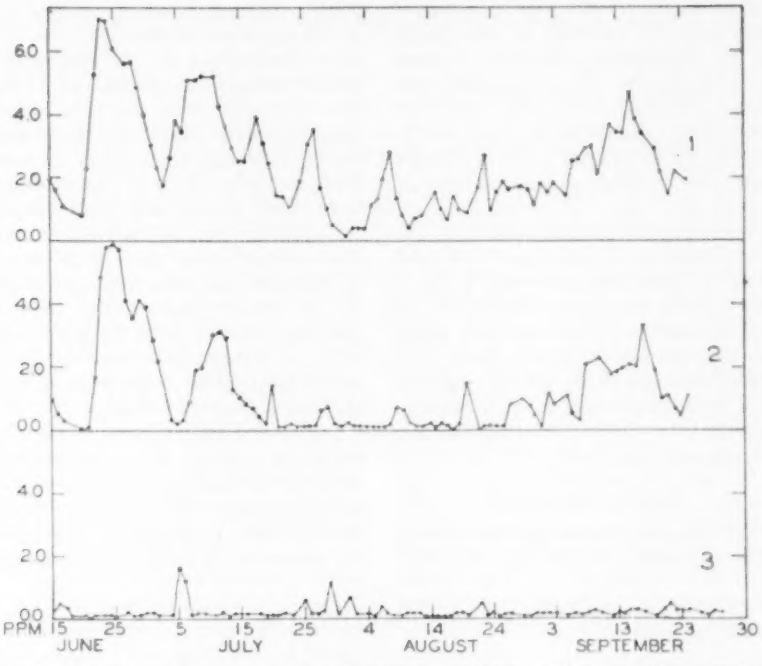

FIGURE 4.—Dissolved oxygen at: (1) North Turner Bridge. (2) Turner Center Bridge. (3) Gulf Island Dam.

at the important sampling stations. The D.O. in the water entering the pool at North Turner Bridge varied from day to day, but became lower and more uniform in the 2-day passage (7 mi.) to Turner Center Bridge (Figure 4). During the slow passage (about 8 days) through the southern half of the pool, more oxygen is removed from the water. Although reaeration in this area of the pool is considerable, the water in the upper layers usually arrives at Gulf Island Dam during the high temperature period with an oxygen content below 0.5 p.p.m. In this area the water near the bottom is, of course, frequently anaerobic. However, the water passing through the wheels at the two dams and over the riffles just south of Deer Rips will rapidly recover oxygen unless conditions are too adverse. For

TABLE II.—Dissolved Oxygen, Androscoggin Pool (Average Daily Values)

Period	Oxygen Content						Oxygen Consumed					
	N.T.		T.C.		Dam		N.T. to T.C.		T.C. to Dam		N.T. to Dam	
	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)
July	14.7	2.80	4.6	0.86	1.2	0.24	10.1	1.94	3.4	0.62	13.5	2.56
Aug.	6.0	1.21	1.8	0.35	0.9	0.18	4.2	0.86	0.9	0.17	5.1	1.03

these reasons, and the fact that nitrate oxygen is not utilized to any extent in the presence of dissolved oxygen, the economic use of sodium nitrate requires the addition to locations in the pool where the water is very low in soluble oxygen content and will become anaerobic in the normal course of events.

Table II contains the statistical dissolved oxygen data averaged for each of two periods and expressed in p.p.m. and in tons per day. These data do not include reaeration oxygen, which has been estimated tentatively to have averaged about 10 lb. per acre per day during the July and August periods, equivalent to about 12.5 tons per day for the entire pool.

Oxygen Consumed

The oxygen consumed from potassium permanganate (O.C.P.) and dissolved oxygen data furnished the principal basis for the daily decisions as to the location for the discharge of sodium nitrate. Cold and hot O.C.P. determinations were made on samples from strategic points and the results were compared with those obtained from the same water on previous days. The extent of the difference between comparable data enabled an approximate estimate to be made of the change in pollution load while passing between two or more points. Most of these analyses were made in the laboratory; when necessary, they were conducted in the field, using a portable gasoline stove as a source of heat.

Figure 5 contains plots of the total oxygen consumed data, hot plus cold, obtained at the three principal sampling stations. North Turner Bridge values yield an adequate picture of the extent of the pollution load passing

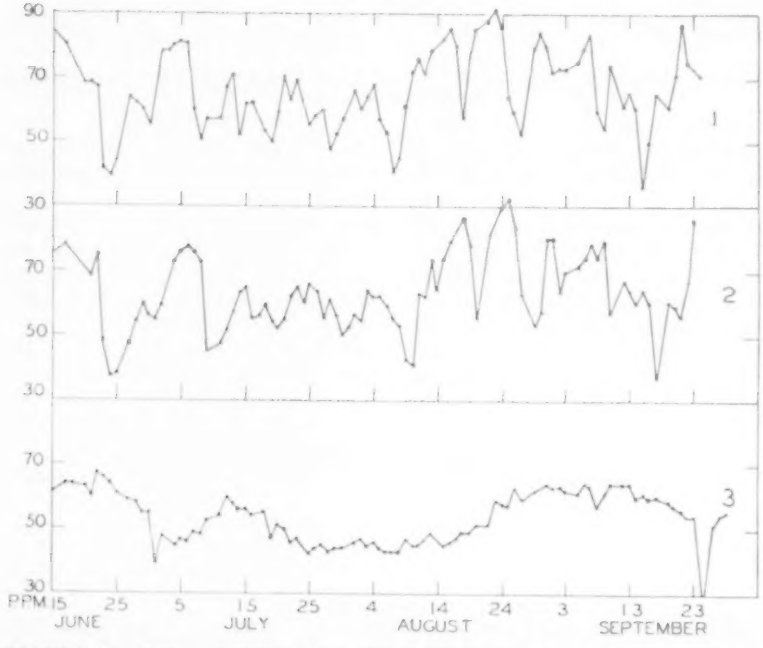

FIGURE 5.—Oxygen consumed from permanganate at: (1) North Turner Bridge. (2) Turner Center Bridge. (3) Gulf Island Dam.

TABLE III.—Oxygen Consumed from Permanganate, Androscoggin Pool (Average Daily Values)

Period	Total at Point						Consumed					
	N.T.		T.C.		Dam		N. T. to T.C.		T.C. to Dam		N.T. to Dam	
	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)	(tons)	(p.p.m.)
July	331	63.0	311	59.0	301	57.0	20	4.0	10	2.0	30	6.0
Aug.	359	72.5	347	70.5	336	68.0	12	2.0	11	2.5	23	4.5

that place. The shapes of this curve and that of Turner Center Bridge results are very similar to that of the compensated production curve (Figure 3). The dates, however, are not comparable, as the time of passage is calculated to Gulf Island Dam.

The daily O.C.P. values obtained at the three chief sampling stations (Figure 5) provide sufficient data for many determinations of the time of detention in the pool (2).

Table III contains a summary of the average oxygen consumed by pollution in the water during passage through the pool. The difference between O.C.P. numbers obtained when the water is entering and leaving the pool (with due allowance for time of passage) is larger than the decrease in B.O.D. values, but the former appear to more nearly reflect the complex situation than do the latter.

Methylene Blue Stability

"Standard Methods" (6) procedure requires a temperature of 20° C. Higher temperatures were used (especially 25° C.) in order to shorten the period for decolorization, but the results obtained, although informative, were not always correlatable with the 20° C. data.

Water containing sodium nitrate has a longer stability test period than does a similar water with the same pollution load and dissolved oxygen content but devoid of or containing a much lower concentration of nitrate. Laboratory tests indicated that micro-organisms do not reduce methylene blue to the leuco state, in the presence of any detectable amounts of nitrate ions. These results are somewhat different from those obtained with sewage by de Waal and Stander (7). Advantage was taken of these facts to save time and effort in studying the distribution of the nitrate after addition to the water. Simultaneous samples were taken; those for possible nitrate analysis were preserved with chloroform, the duplicates being treated with methylene blue. In this manner, more samples may be taken and a better selection made for subsequent analysis for nitrate.

The methylene blue test yielded valuable information as to the approximate time of the appearance of hydrogen sulfide in a sample of water and relating it to the pollution load. As a field control, in the work of inhibiting the formation of hydrogen sulfide, the test is often a very useful aid to judgment, especially when only a short time is required to obtain the leuco state.

Biochemical Oxygen Demand

B.O.D.'s (5-day, 20° C.) were determined on samples obtained every Thursday and also on other days when the results would be valuable for the record. The long period of time which must elapse between sampling and receipt of the results of the test reduce its value for control work with sodium nitrate. The limited data (Table IV) indicate that the decrease in B.O.D. between Turner Center Bridge and the dam was largest dur-

TABLE IV.—Biochemical Oxygen Demand, Androscoggin Pool (5-day, 20° C., in p.p.m.)

Date	Sampling Point		
	N.T.B.	T.C.B.	G.I.D.
June 23	5.20	3.55	9.18
28	3.74	3.52	3.74
30	5.60	5.55	2.50
July 4	8.05	5.00	4.00
7	2.05	3.88	3.15
11	4.35	3.55	6.10
14	4.23	3.95	4.60
18	6.61	5.50	5.50
21	3.85	2.60	2.70
28	4.05	3.70	3.24
Aug. 1	—	—	4.41
4	5.25	4.23	4.10
11	8.60	3.00	3.80
15	7.04	7.98	5.11
18	4.30	8.90	4.45
25	5.35	10.30	4.37
29	—	—	5.57
Sept. 1	5.00	5.10	3.45
8	3.88	4.50	4.95

ing the August period, when the maximum additions of sodium nitrate were being made. Similar results with sewage have been reported by Heukelekian (8).

Addition of Sodium Nitrate

The 100-lb. bags of sodium nitrate were discharged slowly from the boat while traversing the area selected by the administrator. The boat course was "zig-zagged" across the pool area in such a manner as to obtain maximum distribution.

When possible, pelleted nitrate was used, for in this form the material readily sinks and enters the deep water with very little dissolving in the surface aerobic layers. The fine crystalline form was made to penetrate considerable depths by reducing the speed of the boat, but solution in surface waters was larger than with the coarse material. Some batches of nitrate discharged in the region from 3 to 4 miles north of the dam were carried in solution into the lower strata of the deep water downstream by the down-flow produced by the difference in water temperature. This occurred more frequently during the latter part of August and early September when the water entering this area was at times about 1° to 2° C. cooler than that a mile or so southward.

All of the 561.5 tons of sodium nitrate added to the pool were discharged from the boat in the area between Gulf Island Dam and northward to a line designated as mile 4.75. If added uniformly to the water during an average day's flow, 15 tons of sodium nitrate would yield a concentration of about 3 p.p.m. of the salt.

The amounts of nitrate added at the different locations are given in Table

TABLE V.—Location of Sodium Nitrate Additions to Androscoggin River

Date	Location	Tons	Date	Location	Tons
June 18	Chisholm	10	Aug. 18	Riley	5
20	Pool	5.5	19	Riley	5
21	Pool	6	19	Pool	15
22	Pool	10	20	Pool	20
23	Pool	15	22	Pool	15
24	Pool	10	22	Riley	5
			23	Riley	5
July 6	Pool	15	23	Pool	15
7	Pool	10	24	Pool	15
8	Pool	15	25	Pool	13
9	Pool	8	26	Pool	15
14	Pool	12	27	Pool	20
21	Pool	10	27	Riley	5
22	Pool	15	29	Riley	5
27	Pool	15	29	Pool	15
28	Pool	15	30	Riley	5
			30	Pool	20
Aug. 3	Pool	15	31	Pool	10
6	Pool	20			
8	Riley	12	Sept. 1	Riley	5
8	Pool	15	2	Riley	6
10	Pool	15	2	Pool	15
13	Pool	15	3	Pool	15
14	Pool	12	5	Pool	5
15	Pool	12	6	Pool	17
16	Pool	18	9	Pool	13
16	Riley	12	13	Pool	5
17	Pool	20			
18	Pool	15			

TABLE VI.—Sodium Nitrate and Nitrate Oxygen Additions, Androscoggin River and Pool (Tons)

Period	Days in Period	Days NO_3 Added	Location of Addition							
			North of N.T.		Between T.C. and Dam		Total		Average	
			Na NO_3	O_2 Equiv.	Na NO_3	O_2 Equiv.	Na NO_3	O_2 Equiv.	Per Add.	Per Day
July	31	10	0	0	140	70	140	70	14.0	4.5
Aug.	31	24	59	29.5	340	170	399	199.5	16.6	12.9

V. Those added during the July and August periods have been averaged and are recorded in Table VI. Available nitrate oxygen is calculated as being 50 per cent of the sodium nitrate used; the pure compound contains 56.46 per cent oxygen.

A total of 70 tons of nitrate was added to the river at Riley, Me., about 17 mi. north of the pool. These additions were made in order to study the fate of nitrate in this section of the Androscoggin, where conditions may change rapidly due to dams, powerplants, riffles, and small sewer outfalls. The results obtained were inconclusive, due in part to the considerable reaeration in this area. Some of the nitrate arrived in the pool when expected, but much of it became waylaid, and on two occasions a segment of the water in the upper part of the pool was found to have a comparatively large ammonia content.

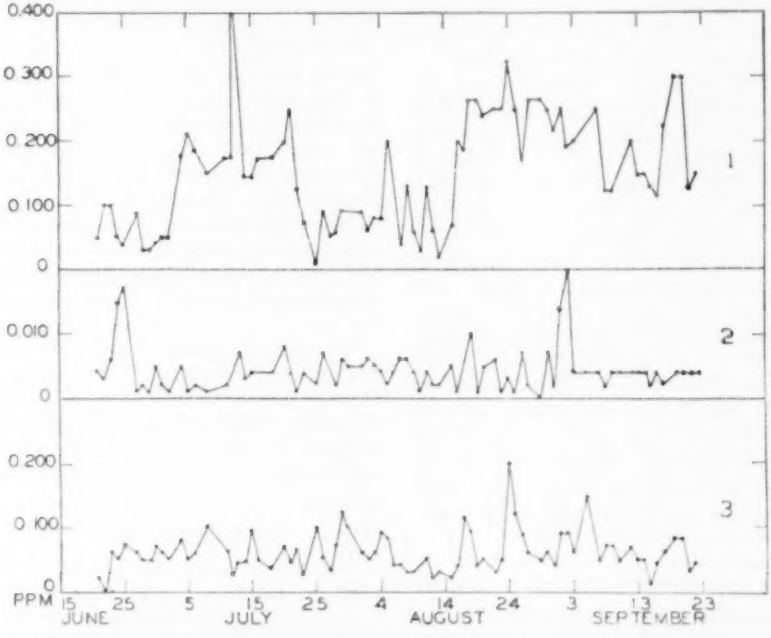

FIGURE 6.—Inorganic nitrogen analyses at Gulf Island Dam station: (1) Ammonia nitrogen. (2) Nitrite nitrogen. (3) Nitrate nitrogen.

Fate of Nitrate Added to Pool

Owing to the intermittent addition of the nitrate to the water, its penetration to different depths with different times of passage to the dams, the existence of stagnant areas in the very deep sections of the pool, and great variations in drawdown at the dams, water samples must be considered as yielding only a qualitative picture of the fate of the sodium nitrate in its passage from the place of addition downstream to the sampling stations at the dams.

A continuous sampler was installed at Gulf Island Dam by tapping off from a continuous flow in an 8-in. pipe that opened into the pool at a depth of 40 ft. Every 24 hr. 20-l. samples were obtained. Adequate amounts of chloroform were maintained in the sampler. Samples were also taken each day, at a depth of 10 ft., just back of the retaining wall. Another sampling station was established at Deer Rips Dam, 1 mi. south of, and about 1 day's time of passage from, Gulf Island Dam.

The analytical nitrogen data obtained from water sampled at Gulf Island (Figure 6), indicate that most of the nitrate was reduced to ammonia in the pool. The increase in the ammonia content of the water resulting from the large applications of nitrate made in August are clearly defined in the plot of ammonia nitrogen. The nitrate and nitrite nitrogen content changed only slightly during the same period. The nitrate in water which passed through the powerhouse at Gulf Island Dam was in part reduced in the Deer Rips pool. On a few occasions, nitrate was added near the dam in order to insure that some would be carried into the lower reservoir.

Nitrogen Content at Various Depths

Samples of water taken at different depths in the area just north of Gulf Island Dam were analyzed for nitrate, nitrite, and ammonia content in order to determine the extent of penetration of sodium nitrate into the deep strata. The data (Table VII) definitely indicate that the nitrate did reach the depths, either directly or indirectly, and that the ammonia content was occasionally relatively high. Most of the high nitrite concentrations were found in deep water sampled near the bed of the pool.

TABLE VII.—Inorganic Nitrogen at Various Depths, Androscoggin Pool

Date	Sampling Point	Depth (ft.)	Nitrogen (p.p.m.)		
			NH_3	NO_2	NO_3
June 27	Mile 0.5	10	0.025	0.001	0.044
		50	0.040	0.002	0.033
29	Mile 1.0	10	0.033	0.002	0.043
		50	0.045	0.002	0.123
July 8	Mile 1.0	10	0.275	0.009	0.066
		50	0.400	0.024	0.026
15	Mile 0.5	50	0.467	0.012	0.138
	Mile 1.0	10	0.450	0.004	0.059
		50	0.275	0.007	0.093
18	Mile 0.25	10	0.250	0.004	0.221
		50	0.400	0.004	0.096
Aug. 8	Mile 1.5	10	0.019	0.002	0.038
		50	0.406	0.088	0.241
18	Mile 0.75	5	0.106	0.003	0.050
		20	0.150	0.002	0.073
		30	0.150	0.004	0.071
		40	0.025	0.005	0.076
		60	0.200	0.005	0.095
25	Mile 0.75	20	0.138	0.004	0.296
		35	0.125	0.005	0.845
		50	0.150	0.004	0.960
		60	0.238	0.004	0.210

Through the summer months there was little variation in the organic nitrogen present in the water. Addition of sodium nitrate to the water did not produce any noticeable change in the concentration of the organic nitrogen compounds.

Hydrogen Sulfide

The objective of the 1949 control program was adjustment of conditions so that the river water entering the canal systems in Lewiston would be free of hydrogen sulfide or would have

a sulfide content so low that the odor from the water would not be objectionable. The maximum amount of hydrogen sulfide found in the canal water was 0.01 p.p.m. on July 21. On August 4, 17, and 18, the concentration was less than 0.01 p.p.m. All other tests were negative. Hydrogen sulfide odor in the air was not detected by an experienced observer from the bridges over the canals or river, or in the downtown areas at any time during the period of control. These conditions were in marked contrast to those experienced during the past 10 years, when the odor of hydrogen sulfide could be detected, in intensities varying from faint to strong, for considerable periods during the summer months. The decrease in hydrogen sulfide, in both the water and the air, during 1948 and 1949 was due to reduction of the sulfite pollution load (partially offset by abnormal low river flow) and to the use of sodium nitrate, which, in an appreciable part of the water, prevented anaerobic conditions or shortened the period of their existence.

The hydrogen sulfide content in the water present in the southern end of the pool varied from 0 to about 1.0 p.p.m. Abrupt changes in concentration were noted at different depths in the same locality, and the deepest strata did not always contain the most hydrogen sulfide. One set of samples from a location where the water is 61 ft. deep gave the following results:

Depth (ft.)	H_2S (p.p.m.)	Depth (ft.)	H_2S (p.p.m.)
5	0.25	40	0.00
20	0.21	45	0.18
30	0.00	60	0.73

Two days later, at the same location, the hydrogen sulfide concentrations were:

Depth (ft.)	H_2S (p.p.m.)	Depth (ft.)	H_2S (p.p.m.)
5	0.00	40	0.00
20	0.12	45	0.36
30	0.15	60	0.25

Although the sodium nitrate additions probably were a factor in producing variations, the ever-changing rate of drawdown at the powerhouses, and the effect of differences in temperature of the incoming water, must also contribute to the stratification pattern. To these must be added the fact that, in the Androscoggin River, the behavior of *Sporovibrio desulfuricans* is at times entirely unpredictable and they may produce appreciable amounts of hydrogen sulfide within a few hours and then decrease their activity.

Plant Stimulation

In the portion of pool where the nitrate was added, the contour of the banks and shores is such that very few aquatic plants are able to establish themselves. Many of the banks are steep and contain little or no top soil in or near the water. The few small areas where aquatic plants grow were inspected from time to time; no observable increase was recorded.

Blue-green algae (*oscillatoria*) have not been observed in any appreciable quantity. When present, they are attached to small pieces of floating sludge or zooglea. Through the summers of 1948 and 1949, the use of sodium nitrate did not produce any significant changes in the blue-green algae population.

Cost of Sodium Nitrate

With the exception of the boat, there were very few expenditures for capital account. Natural Chilean and synthetic sodium nitrate were used in this project, and as the price of the nitrate from each source delivered in Lewiston was different, the costs were averaged at $61.32 per ton.

The expense of trucking to the landing at the pool, adding to the water, testing, etc., approximated $9.00 per ton. The entire control program was financed by the pulp-producing companies.

Analytical Methods

The analytical procedures employed in this project are described in "Standard Methods" (6). Hellige colored-glass reference standards were used for the determination of ammonia and nitrite. Nitrates were reduced to ammonia to avoid interfering substances. Hydrogen sulfide was removed from the sample by nitrogen and evaluated by the zinc acetate, iodine-thiosulfate method.

Summary

1. A total of 641.5 tons of sodium nitrate was added to the Androscoggin River during 44 days in the summer of 1949. Of this amount, 561.5 tons were deposited in the southern portion of the Androscoggin pool.

2. When added to water about to become anaerobic, the nitrate oxygen was readily utilized and ammonia was the principal reduction product.

3. The addition of sodium nitrate permitted a more flexible and economic use of the river as a carrier of sulfite waste liquor by reducing the capacity to create a hydrogen sulfide odor nuisance.

4. Exclusive of capital expenditures, which were relatively small, the nitrate program cost $45,000 and was charged to cost of production account.

5. The 1949 Androscoggin River control program, which includes adjustment of production, as well as the use of sodium nitrate, produced the most favorable summer odor conditions that have existed in the Lewiston and Auburn areas in a decade.

Acknowledgments

Appreciation is expressed to all whose efforts contributed to the completion of this project. The valuable support and assistance given by the companies' representatives—R. A. Webber, Brown Company; E. L. Lamb, Oxford Paper Company; and O. E. Anderson, International Paper Company—are gratefully acknowledged.

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SETTLEABILITY INDEXES FOR ACTIVATED SLUDGE

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Almost since the inception of the activated sludge process as a means of purifying sewage, plant operators have been on the look-out for methods of control which, ideally, and from analysis, would give accurate information relating to the performance and load-carrying ability of the activated sludge process and, at the same time, could be carried out expeditiously in the laboratory. Such a method would give practical and up-to-the-minute assistance in control of aeration processes, instead of just producing the purely "historical" statistics associated with the analytical analyses at present in use as a means of control.

This desirable state of affairs has not been attained, even in the proposed method outlined herein. However, quite a few attempts at a solution to the problem have been made at various times with varying degrees of success. This article is presented as the result of certain work in this connection carried out during 1949 in the laboratory of the Rotherham Sewage Department.

Present Indexes

Apparently, the majority of work on this subject has been carried out in the United States. As far back as 1920, various "sludge indexes" were introduced as a means of assessing the quality of a sample of activated sludge and its ability to purify sewage. The indexes are empirical values, which can be arrived at by any of a number of different techniques, devised by different investigators as follows:

1. Theriault (1), in 1920, determined the suspended solids in p.p.m. by weight of a sample of sludge and the volume of sludge settled in 15 and 30 min. in a 1-l. graduated cylinder.

$$\text{Sludge Index (Theriault)} = \frac{\text{Susp. sol. (in p.p.m.)}}{\text{Vol. settled in 15 or 30 min. (ml.)}}$$

2. Donaldson (2), in 1931, determined per cent suspended solids by weight and per cent settled in 30 min. in a 1-l. graduate.

$$\text{Sludge Index (Donaldson)} = \frac{\text{Susp. sol. (\%)} \times 100}{\text{Vol. settled in 30 min. (\%)}}$$

3. Haseltine (3), in 1932, determined the suspended solids in p.p.m. by weight and per cent settled in 30 min. in a 500-ml. graduate.

$$\text{Sludge Index (Haseltine)} = \frac{\text{Susp. sol. (in p.p.m.)}}{\text{Vol. settled in 30 min. (\%)}}$$

4. Mohlman (4), in 1934, determined per cent suspended solids by weight and per cent settled in 30 min. in a 1-l. graduate.

Sludge Index (Mohlman)

$$= \frac{\text{Vol. settled in 30 min. (\%)}}{\text{Susp. sol. (\%)}}$$

The above indexes vary according to the quality of the activated sludge, their values for poor- and good-quality sludges being as follows:

Index	Quality of Sludge Poor	Good
Theriault (Density)	1.1	25.0
Donaldson (Density)	0.3	2.0
Haseltine (Density)	30	170
Mohlman (Volume)	200	40

Today the Mohlman Sludge Volume Index is the one most extensively used and its corresponding value can be obtained quite easily from any of the other indexes. For example,

$$\text{Mohlman Index} = \frac{100}{\text{Donaldson Index}}$$

$$= \frac{1{,}000}{\text{Theriault Index}}$$

$$= \frac{10{,}000}{\text{Haseltine Index}}$$

Before any attempt is made at solving the all-embracing problem of activated sludge process control, it might be well to investigate the ramifications of such a task. Any test that is carried out to this end must not only be capable of rapid execution, but also should preferably fulfill some or all of the following requirements:

1. The test should give an indication of the load-carrying capacity of the particular aeration plant.

2. The test should give good indication of any change, either for better or for worse, in the ability of the aeration plant to deal with the applied load.

3. In order that effective steps may be taken to make any desirable adjustment in the load on the plant, as mentioned before, it must be possible to arrive at the result of the control determination quickly, and not after the expiration of hours or several days.

Present Indexes as Control Measures

The various sludge indexes are used extensively in the United States, and to a lesser degree in Great Britain, as a means of control for the activated sludge processes, whether in complete treatment or partial treatment plants. As a routine test offering a guide to the successful working of an activated sludge plant, it is claimed by some operators that variations in the quality of the sludge or in the ability of the sludge to do a certain amount of work are indicated by increases in the Mohlman Sludge Volume Index and that, conversely, any decrease in the figure will indicate a decreasing load or a sludge able to do more work. Thus, it is said, the Sludge Volume Index (Mohlman) will give warning of the imminence of bulking conditions and allow of corrective measures being taken to check this condition at the onset.

It might be reasonably argued, therefore, that the sludge indexes in present use in many laboratories make a fair attempt at fulfilling to a lesser or greater degree two of the requirements mentioned above, and approach nearer to control tests for aeration processes than any other, providing the time factor does not materially influence the value of results.

Method of Determining the Mohlman Sludge Index

The Mohlman Sludge Volume Index, which is essentially a laboratory and not a field test, was adopted at the Rotherham sewage works as a prospective means of control of the Sheffield system bio-aeration process. As recommended by "Standard Methods" (5), the determination involves:

1. Determination of the suspended solids settled in 30 min. in a 1-l. gradu-

ated cylinder, from a sample of activated sludge from the aeration tank.

2. Determination of suspended solids in the same sample of sludge. Then,

$$\text{S.V.I.} = \frac{\text{Per cent settling by volume in 30 min.}}{\text{Per cent suspended solids}}$$

Criticism of Sludge Volume and Density Indexes

Effect of Consolidation

One criticism that well may be levelled at the present sludge volume and density indexes is the great effect that consolidation has on the percentage of sludge settled in 30 min. This is illustrated by Curve 1, Figure 1, which clearly indicates that consolidation of the settling sludge commences after about the first 6 min. of the 30-min. period. The consolidation must necessarily mask to a large degree the quality of the sludge as judged by sludge volume and density indexes and, on occasion, tends to give almost similar indexes for sludges of different character. The net result of the consolidation on the sludge index is the pronounced damping effect exerted on the sensitivity of the test, thus producing a very sluggish and not too satisfactory works routine control.

Obviously, a test of this character should be sensitive to a reasonable degree to be of any real practical value and, in this manner, give due warning of any changes taking place within the aeration tank. Insensitivity must, of necessity, lead to insufficient and un-

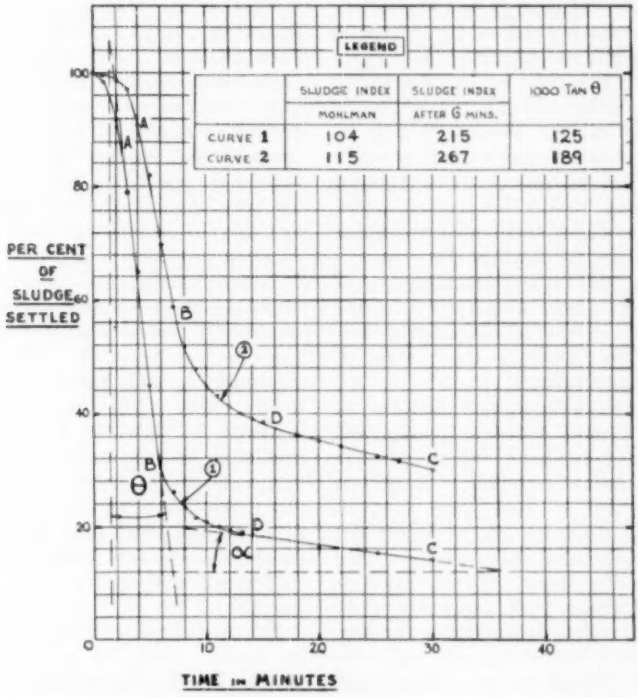

FIGURE 1.—Sludge settlement curves for activated sludge.

reliable warning of the approach of such changes.

Effect of Time Factor

The time factor is very important in any plant control analysis scheme, and particularly so in the case of the control of aeration processes. At the Rotherham works, by substituting the Whatman filter cup for the Gooch crucible in the determination of suspended solids, it was found possible to determine the Mohlman Sludge Index in about 3 hr., along with the other routine analyses. Although this constituted an improvement on the Gooch crucible method, it still was considered to fall short of the practical essentials when taken into account with other undesirable features.

Rate of Settlement

Possibly the most critical factor influencing the control of any activated sludge plant is contained in the information produced by changes in the rate of settlement of the activated sludge solids. In general, it may be said that dense sludges, which settle quickly, are the ones that give the most satisfactory results in aeration processes, and light bulky sludges, which settle with difficulty, are the ones giving the unsatisfactory results. Rate of settlement, then, as applied to the solids in a sample of activated sludge, is a prime factor in the control of aeration processes.

The American sludge indexes at present in use, although taking into account the amount of solids settled in 30 min., cannot reasonably be said to measure, nor in fact were they intended to measure, rate of settlement of the suspended solids uninfluenced by any other factor. Examination of Figure 1 shows that reasonably unrestricted free-falling conditions for particles of activated sludge are easily obtained by plotting the curve of per cent sludge settled against time in minutes, when the unrestricted settlement phase and the consolidation phase are readily seen. In average cases, the free-falling period extends from about the end of the first minute to the 5th to 8th minute. After this period the particles are influenced by the effects of consolidation.

Suggested Sludge Indexes

It appears a well-established fact that a well-aerated good quality sludge invariably settles readily. It would appear that, on examination of all the facts connected with the practical evaluation of any test indicating quality of activated sludge from the point of view of sewage purification, one factor inevitably emerges. This one factor, which gives the most useful guide in assessing the ability of a sample of activated sludge to purify sewage, is the change in the rate of settlement under unrestricted conditions (that is, without consolidation). If this same change in the rate of settlement were actually tied up with the amount of suspended solids present in the activated sludge, this might well become a very useful test to assess the quality of a sample of activated sludge, and thereby to assist in the control of aeration processes.

Unfortunately, although this test might be more "classical" as far as accuracy is concerned, it still suffers from the time factor for manipulation, in which several hours must elapse before the result of the determination is obtained. However, if it is assumed that in an average aeration process the suspended solids content is kept within reasonable limits, the factor of amount of suspended solids may well be eliminated and the sole factor of rate of settlement used to indicate "sludge index."

In this manner, a "Sludge Settleability Index" could be produced in 10 min. by plotting the per cent settlement of sludge *vs.* time curve at 1-min. in-

tervals, thereby producing the unrestricted settlement phase of the traditional curve, in which case the tangent of angle θ (Figure 1) would represent the "Sludge Settleability Index."

Attention is drawn to section A–B of Curves 1 and 2, Figure 1, which represents the unimpeded rate of settlement of a fairly good quality activated sludge and one not so good. It will be seen that point B represents the end of the free-falling phase of settlement, and section B–C the consolidation phase.

Method No. 1

In this method, a graph is drawn of per cent sludge settled *vs.* time in minutes. The suspended solids are determined by filtration through a Whatman filter cup and drying at 100° C.

$$\text{Sludge Settleability Index} = \frac{\text{Sludge settled in 6 min. (\%)}}{\text{Susp. sol. (gm. per 100 ml.)}}$$

It should be pointed out that the consolidation factor is eliminated in this procedure.

Method No. 2

This method, which has been tried out with considerable success at Rotherham, consists very simply of plotting the curve of per cent settled solids *vs.* time for a sample of activated sludge and determining the tangent of the angle subtended by the free-falling portion of the curve (A–B, Figure 1) and the vertical. The curve is produced on graph paper and the readings are taken at 1-min. intervals for 10 min. It is, of course, important that the scale to which the charts are drawn should be of such proportions as to give a reasonably open curve, and the ratio of the x axis units to those of the y axis must be the same for all the curves.

Conclusions

The sludge indexes at present in use clearly indicate large variations in sludge condition (see Figure 2), but suffer from the effect of consolidation

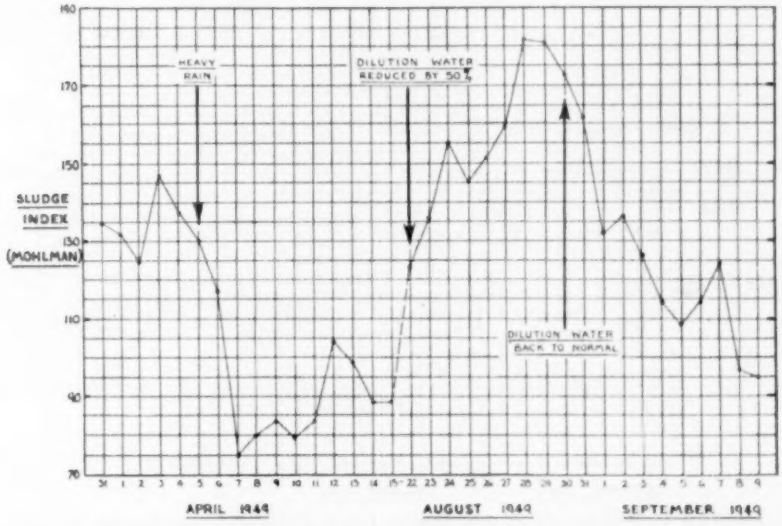

FIGURE 2.—Effect of sludge condition variations on sludge index.

and the time factor. Use of the Sludge Settleability Index (Method No. 1), based on a 6-min. period of settlement in place of 30 min., excludes the consolidation phase, but the time factor still remains.

When the suspended solids content of the activated sludge remains reasonably constant, indication of changes in sludge quality is rapidly illustrated by changes in the Sludge Settleability Index (Method No. 2), as instanced by the slopes of the portions A–B of the sludge settlement curves. This slope, represented by 1,000 tan θ, as observed for a number of samples of the Rotherham activated sludge, is contrasted with the Sludge Settleability Index (Method No. 1) and the Mohlman Index in Figure 3.

The method of sampling can seriously affect the results. For example, the following phenomenon has been observed with occasional samples: The sample as poured from the bottle settled to 80 per cent in 30 min. After gently shaking in the cylinder, it settled to 40 per cent in 30 min. After gently shaking a second time, it settled to 30 per cent in 30 min.; after a third time, to 70 per cent in 30 min.; after a fourth time, to 43 per cent in 30 min.; and after a fifth time, to 44 per cent in 30 min. No doubt, this is due to flocculation and deflocculation occurring during shaking and it would appear that the ideal way of obtaining the sample would be to take the 1-l. graduate and dip it into the aeration tank contents, adjust to the 1,000-ml. mark, and allow to settle for the requisite period.

During the course of the investigations it was observed that there might be some relationship between the slope of the portion D—C of the sludge settlement curve (Figure 1) and the suspended solids content of the sludge.

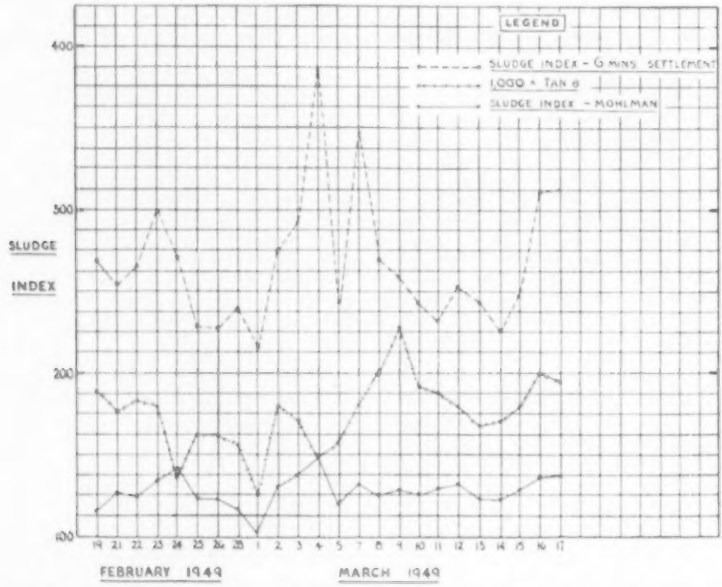

FIGURE 3.—Comparison of variations in activated sludge as indicated by Sludge Settleability Indexes and Sludge Volume Index (Mohlman).

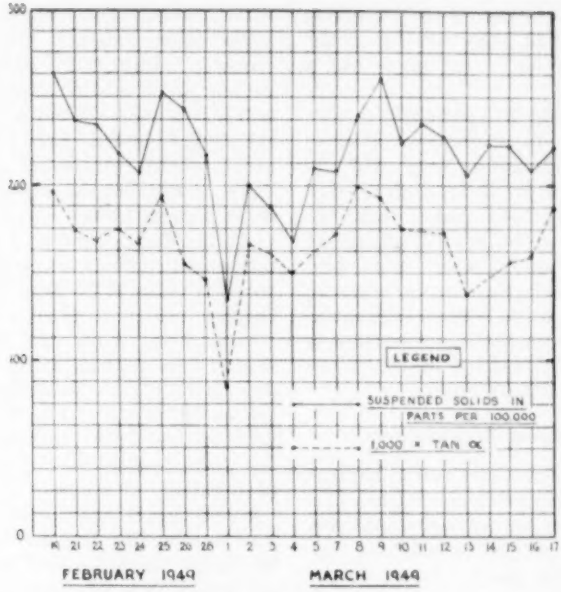

FIGURE 4.—Relationship between suspended solids content of activated sludge with slope of sludge consolidation curve.

Figure 4 shows this factor, as represented by 1,000 a, compared with the suspended solids in parts per 100,000 by weight. However, further research on this aspect is required before any definite conclusions may be drawn.

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OPERATING EXPERIENCES AT GROVE CITY, PA.

By J. N. Hagerich

Operator, Sewage Treatment Plant, Grove City, Pa.

The sewage treatment plant at Grove City, Pa., was designed to provide primary treatment plus secondary treatment of the mechanical aeration, activated sludge type for a flow of 1 m.g.d. However, when the plant was

built (1938) and before the 6 aeration tanks were filled, high water from the nearby creek raised the tanks like a boat.

Despite various expedients—including blasting—to return the tanks to the design elevation, they still remained 8 in. above their original level. As a result, all flows greater than 0.75 m.g.d. would drown out the effluent of the primary tanks, which were provided with mechanical sludge removal. Furthermore, at these flows huge quantities of suspended solids and settleable solids would be carried over into the secondary treatment units.

Attempts at Improvement

Obviously, something had to be done to change the existing conditions. The effluent weir of the primary tanks was raised 6 in., which changed the hydraulics of the plant. In so doing, the flights skimming the surface were flooded out, along with the scum trough. Ordinarily, the scum trough backed up the top liquor so that there was a 3- or 4-in. depth of septic sewage over the entire primary tank surface. With the thought in mind that grease would float almost as soon as it entered the tank, the scum troughs were relocated in the first quarter of the tank and the scum removed manually.

Since the change, the primary effluent weir does not flood out until a flow of 1.2 m.g.d. is reached. In addition, septic sewage does not form on top of the primary tank. Before the change was made, the primary tank removals, averaged over a year, were 65.9 per cent of the settleable solids, 63.3 per cent of the suspended solids, and 44.2 per cent of the 5-day B.O.D.; after the change, removals averaged 90.3 per cent, 72 per cent, and 57.5 per cent, respectively.

Prior to the change, the sludge blanket in the final clarifiers would gradually rise each day between 10 A.M. and noon until it ran over the effluent weirs. The changes in the primary tanks relieved this condition partially, although on days of heavy loading quick manipulation by the operator was the only means of keeping the sludge blanket down. The sludge index would remain at an average value of 500, but on some days would be as high as 1,000.

At the design flow of 1 m.g.d., the theoretical detention period in the aeration tanks is 7.5 hr. The average summer flow at the plant is 0.75 m.g.d. During 6 hr. of the day, the 1-m.g.d. rate of flow prevails at the plant, but during the night sewage flow drops as low as 0.3 m.g.d. Thus, the daylight flow received 7.5-hr. aeration, but the low night flow received as much as 17-hr. aeration. A study of the situation revealed that it was the low night flow that was causing the trouble, as after the sludge blanket would fall the effluent would clear up until only 1 or 2 p.p.m. suspended solids remained.

Digester supernatant, which was usually lagooned, was tried as a sludge settler. Addition during the daytime did not give the hoped-for results, however, as it was the low night flows that were causing the final clarifier trouble.

1949 Changes

In May 1949, in an effort to increase the flow capacity of the secondary units, the effluent weirs of the aeration tanks were lowered 2 in. This adjustment reduced the detention period slightly. At the same time, one of the 6 aeration tanks was taken out of service altogether. From January through April, the relative stability averaged 92 per cent, but during May it fell to 75 per cent. The aeration tank weir adjustment, however, brought the relative stability value back up to 97 per cent, at the same time increasing the plant's flow capacity from 1.22 to 1.42 m.g.d. B.O.D. removal after the change averaged 96.9 per cent.

The unbalanced loading on the aeration tanks continued to cause trouble, however, and remained the No. 1 headache in operation of the plant. In larger plants, using diffused air, 3-shift operation permits reduction in air as the loading is reduced. With mechanical aeration, however, air is supplied at the same rate throughout the 24 hr., resulting in over-aeration during low load periods. At Grove City, moreover, equalization of aerator loading by return of supernatant liquor to the aeration tanks could only be accomplished during the 8-hr. period of operator attendance.

To remedy this shortcoming, a time switch was installed on the supernatant pump, so that supernatant could be returned to the influent of the aeration tanks during low load periods at night, and thus even out the load on the aeration process. With this arrangement, hourly samples over a 24-hr. period showed the sludge index varying from a low of 87 to a high of 212, with an average value of 135 for the month of September. The problem of disposing of the supernatant was also solved for much of the year by this method of operation, as lagooning is necessary only when lack of drying bed space precludes withdrawal of sludge from the digester and increases the solids content of the supernatant.

Digester Heating Is Poor

The primary digester at the plant is in need of draining and cleaning. In addition to the grit accumulation in the bottom, there are undoubtedly some leaks in the heating coil piping. Furthermore, additional heating coils should be installed while the digester is drained, as with the present coils it is impossible to raise the digester temperature to more than 80° F.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"If you don't get everything you want, think of the things you don't get that you don't want."
Anon.

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Kenosha, Wis., Sewage Treatment Plant for 1949

By Frank I. Vilen, *Superintendent*

The Kenosha, Wis., sewage treatment plant provides primary treatment with separate sludge digestion and gas utilization. Full utilization of plant capacity has been limited in past years because of the build-up of toxic copper concentrations in the digesters, due to brass wastes.

The calendar year 1949 was the first in the 9 years of plant operation when all of the dry-weather flow from the city was treated. The 100 per cent increase in plant load over that in 1947 resulted from taking into the plant all of the sewage flow tributary to a major trunk sewer previously by-

passed because of toxic copper wastes. The additional plant load (11.4 m.g.d. as compared with 5.72 m.g.d. in 1947) naturally imposes a greater burden on all equipment and treatment facilities and, when coupled with the 10-yr. age of the equipment, increases maintenance costs. In addition, the flow is now 14 per cent greater than the design load. However, despite some decrease in plant efficiencies over those of previous years, results are still satisfactory for primary treatment of sewage.

Additional increase in load is foreseeable as the community grows, but some relief may be expected with completion of the storm-water diversion program now planned. Considerable relief could be gained, especially during peak storm conditions, by removal from the system of the hundreds of roof drains now overloading it.

Industrial Wastes

Continued attention was given to industrial wastes which might have a deleterious effect on sewage treatment. Regular laboratory tests were made on copper concentrations in raw and digester sludges. The copper concentration in digester sludge for 1949 was 0.44 per cent, as compared with 0.35 per cent in 1948.

Several conferences in 1949 have resulted in a study by the officials of a local industry to seek a method for neutralizing acid pickling wastes before discharge into the sewer system. Attention is also to be given to eliminating the discharge of objectionable wastes from another local industry.

Regular laboratory analyses for grease were made in 1949 as in past years. The average in raw sludge was 27.6 per cent, a 2 per cent increase over the previous year. The grease concentration in digester sludge averaged 13.5 per cent, or a reduction of 51 per cent.

Miscellaneous

The annual cleaning of the Pike Creek interceptor each winter, and its coincident change in sewage characteristics, has an adverse effect on digestion. Gas production falls below normal when it is most needed, and in 1949 it was necessary to purchase gas for additional fuel in the amount of $102.74. The sewage treatment plant is also forced to purchase additional electric power for pumping during this period of low gas production.

Operation data for 1949 are summarized in Table I.

TABLE I.—Summary of 1949 Operating Data, Kenosha, Wis., Sewage Treatment Plant

Item	Average
Rainfall (in.)	29.67
Sewage flow (m.g.d.)	11.40
Grit (cu. ft. daily)	4.1
Raw sludge:	
Dry solids (lb. per day)	9,350
Volatile dry solids (lb. per day)	5,690
Sludge gas (cu. ft. per day):	
Produced	46,200
Consumed	33,870
Digested sludge withdrawn:	
Wet sludge (gal. per day)	1,530
Solids (%)	0.53
Volatile matter (%)	53.6
5-day B.O.D. (p.p.m.):	
Influent	101
Final effluent	60
Reduction (%)	41
Suspended solids (p.p.m.):	
Influent	150
Final effluent	70
Reduction (%)	56
Chlorine used (lb. per day)	374
Total (lb.)	120,000
Demand (p.p.m.)	4.4 to 6.5
Electrical energy used (kw.-hr.)	174,650
Operating costs ($):	
Total for year	59,220.96
Per m.g.	14.29

Annual Operation Report of the Ann Arbor (Mich.) Sewage Treatment Plant for the Year 1947 *

By C. Preston Witcher, *Superintendent*

The results obtained in 1947 were eminently satisfactory, especially when the adverse conditions under which the plant operated are considered. The plant was designed as a 4.5-m.g.d. plant with 12 min. of preaeration, 1 hr. of primary settling, 6 hr. of aeration, and 2¼ hr. of final settling, or a total plant detention time of approximately 9.5 hr. The average flow during 1947 was 6.6 m.g.d., which reduced the total treatment time to 6.8 hr. On an average basis this would not have been too difficult, but instead of momentary peak flows of about 6.5 m.g.d. for the 4.5-m.g.d. average design flow, the plant has had to contend with prolonged peak flows (9 hr. daily) of over 8 m.g.d. for an average 6.6-m.g.d. flow.

Activated Sludge

Peak flows are of utmost importance in activated sludge treatment as far as the settling rate of the sludge is concerned. Obviously, a slow-settling sludge, which might be accommodated successfully in final tanks having 2 hr. or more detention, might be much too slow to settle in tanks providing only 1 hr. detention. Therefore, it has been necessary to maintain a fast-settling sludge at all times, as the final settling time is only about 1 hr. at the prevailing peak rates of flow. Actually, the time is much less than this, because at high flow rates short circuiting is aggravated. Some idea of the high final tank velocities may be gained from the weir overflow rates of around 15,000 g.p.d. per foot of weir, instead of the 8,000 to 9,000 g.p.d. contemplated in the original design, and the tank overflow of over 1,500 g.p.d. per sq. ft. at peak flow rates.

Maintenance of a sufficiently oxidized activated sludge of proper settling characteristics is dependent, of course, on the aeration cycle. The original design of the aerators was calculated on a basis of about 5,000 lb. 5-day B.O.D. per day, or about 26 lb. per 1,000 cu. ft. of aeration tank volume. Approximately 1,000 cu. ft. of air was provided for every 1.9 lb. B.O.D. These design values provide fairly well for maintaining enough activated sludge to adequately treat 5,000 lb. B.O.D. per day and insure a properly functioning aeration cycle. In 1947, an average of 9,300 lb. 5-day B.O.D. was applied per day. This was at the rate of about 48 lb. per 1,000 cu. ft. of aeration tank volume. The available air supplied only 1,000 cu. ft. of air for each 1 lb. B.O.D. applied. In other words, the aeration cycle operated at 86 per cent over its designed capacity on an average basis, and at well over 100 per cent overload on most weekdays.

The detention period in the primary tanks has been reduced to between 30 and 40 min. This shorter period increases the velocities through the tanks, resulting in more load being carried through to the secondary process. Under present operating conditions, provisions for scum removal from the final tanks would be a valuable asset. Mechanical skimmers have been installed in the primary tanks and are a decided help in continuously removing all scum that forms, but a considerable amount of material never reaches the surface and is carried through to the secondary process.

The worst feature of the short detention time in the primary tanks is encountered when trying to waste activated sludge. The only available method of wasting this material is by

* For last previous extract see: *Sewage Works Journal*, **20**, 5, 914 (Sept., 1948).

pumping it to the incoming sewage for settling and removal in the primary tanks. When a waste sludge of proper settling characteristics is settled out during the low flow period (about 2 A.M. to 8 A.M.) not too much trouble is encountered, but it is almost impossible to get rid of a poorly settling sludge with the facilities available. In July, a slug of phenolic industrial waste completely destroyed the settleability of the activated sludge. Normally, with sufficient capacity to waste the poor material out of the secondary process, proper operating conditions could have been re-established within 24 hr. As it was, it took about 5 days to get back to normal, during which time the waste sludge was returned to the primary tanks, failed to settle out and be removed as intended, came back to the secondary process in worse condition, if possible, than when it was originally wasted, got into the final settling tanks, and boiled up into the final effluent. For almost a week there were about twice as many suspended solids going out in the final effluent as were being received in the raw sewage, all because of inability to get the waste sludge out of the system.

Digesters

The two digesters are doing a remarkable job of digestion, but are so overloaded that there is no time for separation and compaction of sludge. The average volatile loading has been 1 lb. per day for each 17 cu. ft. of capacity, as compared with a desirable loading of 1 lb. per day for each 30 cu. ft. of capacity. The detention period in the tanks has averaged 22½ days, whereas 50 to 60 days are required for proper separation and compaction. The high loading rates have caused considerable trouble in maintaining tank temperatures and in maintaining alkaline conditions in the primary-stage digester. Auxiliary water heaters have been rigged up to keep the tanks from dropping below 70° C. in the winter time. By continuous recirculation of the primary digester, and occasional back circulation of second-stage sludge to the primary, it has been possible to maintain alkaline conditions and a high rate of digestion. The reduction of volatile matter was 43.5 per cent, a rather low value. It is only when considering the small capacity available for this reduction that some idea is gotten of the rate at which digestion had to be accomplished. The resulting digested sludge is only 1.3 per cent solids and is disposed of principally by lagooning, as the daily

TABLE II.—Summary of 1947 Operation Data, Ann Arbor, Mich.

Item	Average
Total rainfall (in.)	31.60
Connected population	60,000
Equivalent population (B.O.D.)	65,000
Sewage treated (m.g.d.)	6.6
Suspended solids (p.p.m.):	
Raw	176
Settled	107
Final	11.8
Per cent reduction	93
B.O.D. (p.p.m.):	
Raw	201
Settled	169
Final	13
Per cent reduction	94
Activated sludge:	
Mixed liquor solids (p.p.m.)	1,850
Aeration period (hr.)	4.0
Air used (cu. ft. per gal.)	0.9
Return sludge solids (p.p.m.)	5,500
Amount return sludge (% by vol.)	31
Raw sludge:	
Total solids (%)	2.8
Volatile solids (%)	76.9
Supernatant:	
Total solids (%)	0.60
Volatile solids (%)	61.0
Digested sludge:	
Total solids (%)	1.3
Volatile solids (%)	65.3
Digester gas:	
Cu. ft. per capita per day	0.94
Operation cost ($):	
Per m.g.	23.73
Per capita	0.95
Total cost (including all charges) ($):	
Per m.g.	37.67
Per capita	1.51
Amount earned for depreciation ($)	12,216.83

volume is far beyond the capacity of the vacuum filter.

Miscellaneous

A new lagoon, excavated during the summer and covering about 5 acres, already is about half filled. It is very doubtful if it will last through 1948. Almost every weekday, thousands of gallons of raw sewage by-pass directly to the river ahead of the plant through a diversion line that takes any flow above the hydraulic capacity of the line into the plant.

With every tank and piece of equipment indispensable, a single breakdown would necessitate by-passing sewage and would force reversion to whatever type of treatment the remaining facilities could accomplish.

Plant operation for 1947 is summarized in Table II.

BETTER JOINTS FOR CLAY SEWER PIPE *

By Harry J. Rosenthal

Clay Products Association, Lincoln, Nebr.

No sewer line is better than its weakest part, which usually means its joints. The making of better joints is, therefore, of prime importance in sewer construction and maintenance. For the past ten years, the Clay Products Association, in cooperation with the Armour Research Foundation and the Clay Products Institute of California, has been working to develop a jointing compound low in cost, simple in composition, and with which it is easier and quicker to make sewer pipe joints right than wrong.

Ideal Specifications

When the search for a perfect jointing compound was started it was decided that the ideal specification for such a compound should be:

1. Adhesiveness to glazed clay pipe surfaces.
2. Imperviousness toward the action of acids, salts, or other disintegrating substances found in sewage.
3. Permanence in the joint—that is, the absence of any tendency to shrink or embrittle over a long period of years.
4. Pourability, or the property of being easy to run at the time the material is being applied to the joint.
5. Sufficient mechanical strength to support the spigot of the pipe in the bell without squeezing the material out of the bottom. Also, sufficient stiffness to resist the penetrating onslaught of roots pushing against its surface.
6. Capable of being reheated without spoilage.

Present Types

In undertaking the development of a compound to meet these ideal specifications, tests were first made of all the types of jointing compounds on the market. These fall into four general classes: cement, mastic, mechanical, and hot pour.

Cement joints are rigid and subject to disintegration from destructive elements, such as chemically active sewage, industrial wastes, and acids formed by the oxidation of hydrogen sulfide in the sewer. However, the cement mortar joint is protected by the clay pipe itself, except for the small opening at the joint, so in stable ground where the pipe is not liable to

* Presented at 21st Annual Convention, North Dakota Water and Sewage Works Conference; Dickinson, N. Dak.; Oct. 6–7, 1949.

shift, a cement joint properly made should be satisfactory.

Mastic joints may be of the cold, troweled, asphaltic type, or they may be composed of sodium silicate cements. As most of the asphaltic mastic joints depend on oxidation and evaporation for their set, they usually remain soft in the joint. Having no structural stability, the weight of the pipe and ditch filling usually pushes them out of the bottom of the joint space, thus leaving an opening in the joint at the top of the pipe.

Sodium silicate cements are mixed on the job, much as are ordinary cement joints. Being entirely resistant to acids, these compounds may be used where extreme acid conditions are expected. They will not withstand sewage carrying alternate acid and alkaline wastes, for they are soluble in alkaline wastes and will wash away.

Several synthetic resins on the market may be mixed cold at the job site. After mixing, they depend on chemical reaction between their powder and liquid for their set. They are quite expensive (35¢ per lb.), but have the advantage of being resistant to strong acid or alkali wastes. Recently, some apparently satisfactory synthetic rubber compounds have been marketed. They are putty-like substances before hardening, and are extruded from a gun. Although expensive (30¢ per lb.), they will withstand acids, alkalies, and all common solvents. By the above process, clay liner plates have been sealed-in at the joints with a bead of the material protecting a cement joint.

Mechanical joints are made in the manner of pouring a collar of asphalt or cold tar on the spigot end of the pipe and another collar of the same material around the inside of the bell. A solvent is wiped over the surfaces of these two collars before the bell and spigot are forced together under pressure. The solvent makes the asphalt surfaces tacky, thus allowing the two surfaces to knit together. A rubber gasket type of joint is also on the market, but the pipes must be almost perfect in dimensional measurements before the joints will fit properly.

There are over 40 different patented types of hot-pour asphalt and sulfur-silica jointing materials on the market. Tests of these various commercial compounds showed many of them to be good, but none fulfilled all 6 of the requirements established for the more perfect compound.

Test Results

No attempt will be made to go into detail on the thousands of tests made of various types of compounds, or the accelerated root penetration experiments on compounds of almost every conceivable combination. Suffice it to say that the results of 10 years' experimentation resulted in two compounds that can be unhesitatingly recommended for sewer work. The two compounds are known as ClaPipe Compound and CPI–2. ClaPipe Compound is composed of a coumarone resin, a plasticizer, and powdered silica. It is of a yellowish hue, melts and pours easily, and displays excellent adhesion to clay sewer pipe. It has more flexibility than CPI–2 being about as flexible at 60° F. as CPI–2 is at 80° F. Because ClaPipe Compound is more expensive than CPI–2, probably its only recommendation for use in preference to CPI–2 would be in the event that a higher degree of flexibility was desired. Both exhibit excellent resistance to root penetration.

CPI–2 Compound is a coal-tar product that melts and pours readily at about 350° F. It will adhere excellently to a clean, dry pipe, but will not stick to a damp, oily, or dirty pipe. For such conditions the simplest and best primer is a solution of paraffin in petroleum thinner. Proportions of 1 lb. of paraffin to 1 gal. of thinner works out well.

Where prejointed units are prepared, one pipe section is stood upright on a flat surface, bell end up, and the spigot end of a second pipe is centered in the bell. To prevent the compound from running through into the inside of the pipe, about 1 in. of the annular space is packed with oakum or jute. Where more than two sections of pipe are jointed in the above manner, a vertical rack will insure perfect alignment of the pipe while the joints are being poured.

When joints are poured in the trench, more care should be taken to obtain a water-tight joint. Jute is packed into the annular space as before. It not only seals the joint, but also centers the spigot of one pipe in the bell of the other. A snake or runner is wrapped around the barrel of the pipe tight against the bell of the preceding pipe and clamped into position. Moist clay is smeared between the runner and the pipe and a pouring gate is formed of clay at the top. The gate should be placed slightly off center at the top of the pipe so that the compound will flow around one side, thus allowing entrapped air and gases to escape ahead of the flowing compound and eliminating the formation of air pockets and holes in the joint compound after it is set.

TIPS AND QUIPS

Root and Fungus Control

"Copper Sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains," by John W. Hood, Superintendent of Sewage Treatment, Ridgewood, N. J., is the title of a timely treatise issued by the Phelps Dodge Refining Corp. The 24-page booklet deals with the various aspects of sewer and drain stoppage by root and fungus growths, from the viewpoints of both municipalities and home owners, and the method of alleviating such trouble through the use of copper sulfate. In addition to the factors of mechanical obstruction of pipes, odor nuisance, and deterioration of structures, the author cites the difficulties attendant on reduction in capacity of facilities and receipt at the treatment plant of stale sewage, with resultant increased treatment costs.

Although no apparent damage is done to shrubs and trees whose roots have penetrated sewers treated with copper sulfate for their control, the corrosive action of the chemical on metal pipes must be recognized, particularly in the case of interior plumbing. Therefore, when dosing house sewer connections, the porcelain toilet bowl is always used and never the sink or other trapped fixture. Additional flushing water is required, so that the crystals of chemical are carried beyond the soil pipe system in the house and into the root-obstructed tile pipe outside the premises.

Control of the copper concentration in the treatment plant influent is obtainable through control of the quantity of chemical used in the collection system at any one time. The required dosage in any limited area to be treated is dependent on the total mass of roots present in the sewers of that area. Comparison of the pH-alkalinity value of a sewage with that of its water supply is used as an indicator of the general condition in the sewer, as well as of the beneficial results being obtained by treatment.

In mains and laterals, application of copper sulfate is by introduction of the crystals (medium size preferred) into the flow at manholes. Some flow must be present; if complete obstruction is encountered, mechanical means

are necessary to start the flow. Low flow periods are best, as the concentrations are highest at this time. Annual preventive doses are recommended following the reduction of the first root mass.

Internal accumulation of biological growths in pumps and force mains may be effectively reduced by hanging a bag of copper sulfate crystals in the inlet to the storage well.

Copies of the booklet may be obtained from Phelps Dodge Refining Corp., 40 Wall Street, New York, N. Y.

"Bicycle" Bosn's Chair

A new "bosn's chair" type of cable suspended, tubular steel, 1-man platform hoist has been introduced. Sitting on a bicycle-type saddle, the worker operates standard bicycle pedals to raise or lower the hoist by means of an efficient chain-driven winch. Movement of the hoist by foot power may be as fast as 25 ft. per min., either up or down, at the same time leaving the worker's hands free for other duties. Weighing only 75 lb., the unit can be handled by one man, and is rigged quickly for work in any location. The cable suspension is such that the cage will always hang in an upright position, with no possibility of tilting. Waist-high guard rails and a metal-mesh bottom tray are additional safety features, as are also the 3 automatic mechanical safety devices on the winch mechanism.

The hoist is claimed to be useful on inspection, maintenance, and repair work on all sorts of walls, tanks, shafts, and other vertical surfaces, whether above or below ground.

FIGURE 1.—Pedal-driven, tubular, one-man hoist for work on vertical surfaces.

Digester Scum Reduction

Indications that application of Cloroben to sludge digesters results in better supernatant and higher solids content in the digested sludge, as well as reduction in the thickness and solids content of the scum blanket, were described by A. H. Reiners, Cloroben Corp., Jersey City, N. J., in a paper presented at the 1950 Annual Meeting, New Jersey Sewage Works Association, held at Trenton, N. J., March 22–24, 1950. As a panel member in "The Manufacturers Speak" forum, Mr. Reiners made a preliminary report on results recently obtained at three treatment plants where the compound was applied to digesters under controlled conditions.

One plant receives only domestic sewage; the second, mixed industrial and domestic sewage. The third plant receives a large proportion of indus-

trial wastes from a large tannery. In each of the first two cases, the primary effluent is treated with alum and the sludge is pumped to a single-stage heated digester with floating cover. Both digesters showed an accumulation of heavy scum. Before treatment was started samples of the scum taken at various depths were analyzed for total solids, ash, and grease. During treatment, the sampling was repeated at intervals of 1 to 3 weeks.

Treatment was started by adding a dilution of the chemical to the top of the scum blanket through the gas vents and center dome. The dosage, calculated on the basis of volume, was applied over a 3-day period in equal quantities as a 15 to 30 per cent dilution. Thereafter, the required volume of chemical was added daily, as a 1 to 5 per cent dilution, in the raw sludge pumped to the digester. After a couple weeks the scum blanket showed an appreciable reduction in solid content and depth. Further indications of increasing scum solids were quickly dissipated by supplementary treatments with 1 or 2 gal. of the chemical at the vents. In all cases, gas production continued at normal rates.

At the plant handling only domestic sewage, a scum blanket estimated to be over 5 ft. thick was reduced in 79 days to 2 ft. The Cloroben dosage in this case was 100 p.p.m. At the plant treating domestic sewage and industrial wastes, a chemical dosage of 200 p.p.m. reduced the scum from its original 4.5-ft. thickness to about 2 ft. in 50 days.

At the plant handling heavy tannery waste flows (about 20 per cent of the total volume), Cloroben was originally added at the plant inlet for odor control in the 9-m.g.d. flow, which receives primary treatment. After two-stage digestion, the sludge is conditioned with ferric chloride and dewatered on vacuum filters.

About two weeks after starting Cloroben dosage of the digesters in the spring of 1949, the filter cake showed numerous nodules, which were found to be hair balls. When the chemical dosage was stopped, the hair balls persisted for about two weeks, but gradually disappeared. Two weeks after resumption of the treatment, hair balls reappeared on the filters. Scum thickness was reported to be decreasing.

Experiments are now underway at this same plant with one set of digesters receiving 100 p.p.m. Cloroben and the other, acting as a control, receiving no treatment. Results of this study are expected to be reported at an early date.

Forged Aluminum Manhole Steps

Forged aluminum manhole steps and ladder rungs (Figure 2) for municipal and industrial installations are now being marketed. The new steps, forged from high-strength aluminum alloys, are available in three sizes, adaptable to concrete, brick, or concrete block wall construction according to the projection required. The alloys used are highly corrosion resistant, strong, and non-sparking, all characteristics essential in uses where corrosive or explosive atmospheres are present.

FIGURE 2.—Aluminum alloy manhole steps are non-sparking and corrosion resistant.

Proceedings of Member Associations

TEXAS SEWAGE WORKS SECTION

1950 Annual Meeting

College Station, Texas, March 12–16, 1950

The 1950 Annual Meeting of the Texas Sewage Works Section was held during the Thirty-second Texas Water and Sewage Works Association's Short Course at Texas A. & M. College. The Short Course was in session from March 12 through 16, 1950. All previous attendance records were broken with the registration numbering 514.

A splendid diversified program was planned for those attending the sewage works sessions. Subjects covered included: sewer ordinances, construction, financing, and maintenance; sewage treatment processes, the problems involved, and the effect of industrial wastes on these processes; disposal of sludge and effluents; treatment plant records; and coordination of pollution surveys with remedial action. An industrial waste disposal symposium and a roundtable discussion also were features of the program.

The annual business session was held on March 14, with Chairman I. M. Dietz presiding. The following officers were elected:

Chairman: S. L. Allison, Corpus Christi.
Vice-Chairman: C. H. Connell, Galveston.
Secretary-Treasurer: V. M. Ehlers, Austin.
Asst. Secretary: Mrs. Earl V. Goodwin, Austin.

The Federation was represented by President A. H. Niles, who gave a brief history and resume of current Federation affairs at the business meeting.

V. M. Ehlers,
Secretary-Treasurer

LOUISIANA CONFERENCE ON WATER SUPPLY AND SEWERAGE

1950 Annual Meeting

Baton Rouge, La., March 15–17, 1950

The 1950 Annual Meeting of the Louisiana Conference on Water Supply and Sewerage was held at Louisiana State University, Baton Rouge, March 15–17, 1950, in conjunction with the 13th Annual Short Course for superintendents and operators of water and sewerage systems. The meeting had a total registration of 75, an increase over last year's attendance.

The morning session of the first day was a joint meeting featuring a discussion on "The Problem of Water and Sewerage Extension in a Growing Community." The program for those attending the sewage works sessions consisted of the following papers:

"Sewage Treatment — What it Does," by George M. Sallwasser, as-

sistant regional engineer, Louisiana State Health Dept.

"Experiences with a New Plant," by Ben S. Graves, superintendent, sewage treatment plant, Shell Oil Company, Norco, La.

"Plant Control Tests," by J. A. K. van Hasselt, public health engineer, Louisiana State Health Dept.

"Sewer Construction," by Fred Smith, Carnegie & Smith, consulting engineers, Baton Rouge.

"Jointing Material," by W. A. Wintz, Jr., assistant professor of civil engineering, Louisiana State University.

"Municipal Sewer Ordinance," by A. B. Ritter, regional engineer, Louisiana State Health Dept.

An inspection trip to the Brookstown sewage disposal plant (Baton Rouge) proved to be an interesting supplement to the meeting.

At the business session on March 16, the following officers were elected:

Chairman: H. W. Blakeman, Rayville.
Vice-Chairman: L. J. Dore, Lafayette.
Secretary-Treasurer: S. V. Hazlip.

S. V. Hazlip,
Secretary-Treasurer

KANSAS SEWAGE WORKS ASSOCIATION

Fifth Annual Meeting

Salina, Kansas, April 19–21, 1950

The Fifth Annual Joint Meeting of the Kansas Sewage Works Association and the Kansas Section, AWWA, was held at the Lamar Hotel in Salina, Kansas, on April 19–21, 1950. At a special session for sewage plant operators on the afternoon of April 19, two roundtable discussions were featured. Subjects considered by the panels included plant beautification and safety, jointing of sewers, construction of house services, manhole spacing and construction, sludge digestion and disposal problems, trickling filter operation, and operation and maintenance of pumps.

Other papers of interest to those concerned with sewage and industrial wastes treatment problems were:

"The Effect of Industrial Wastes on Sewage Treatment at Topeka," by D. B. Kissinger, superintendent of sewage treatment, Topeka.

"Needed Legislation for Pollution Abatement in Kansas," by P. R. Shanahan, representative, Kansas Legislature.

"The Kansas River Basin Water Pollution Investigation," by P. D. Haney, senior sanitary engineer, U.S.P.H.S., Cincinnati, Ohio.

At the Annual Luncheon and Business Meeting on April 21, the following new officers were elected to serve for the coming year:

Chairman: D. B. Kissinger, Topeka.
Vice-Chairman: Roy Binder, Hays.
Secretary-Treasurer: D. F. Metzler, Lawrence.

Dwight F. Metzler,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Ohio Sewage and Industrial Wastes Treatment Conference	Gibson Hotel, Cincinnati, Ohio	June 28–30, 1950
Pennsylvania Sewage and Industrial Wastes Association	Pennsylvania State College, State College, Pa.	Aug. 23–25, 1950
Canadian Institute on Sewage and Sanitation	Bigwin Inn, Lake of Bays, Ont.	Sept. 11–13, 1950
West Virginia Sewage and Industrial Wastes Association	Hotel Pritchard, Huntington, W. Va.	Sept. 14–15, 1950
Iowa Sewage Works Association	Hotel Blackhawk, Davenport, Ia.	Sept. 19–21, 1950
Georgia Water and Sewage Association	Ga. Institute of Technology, Atlanta, Ga.	Sept. 20–22, 1950
Rocky Mountain Sewage Works Association	La Fonda Hotel, Santa Fe, N. Mex.	Sept. 27–29, 1950
Missouri Water and Sewerage Conference	Sheraton Hotel, St. Louis, Mo.	Oct. 1–3, 1950
Federation of Sewage Works Associations	**Hotel Statler, Washington, D. C.**	**Oct. 9–12, 1950**
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Memphis, Tenn.	Oct. 23–25, 1950
North Carolina Sewage Works Association	Washington-Duke Hotel, Durham, N. C.	Nov. 13–15, 1950

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(D) P. F. T. Pressure gauge on gas supply line.

(E) P. F. T. 2" Low Pressure Check Valve on digester gas supply line. (a second unit not shown)

(F) P. F. T. 2" Pressure relief and Waste Gas Flame Trap on line to P. F. T. 3" Waste Gas Burner (not shown).

(G) P. F. T. Five Scale Pressure Gauge.

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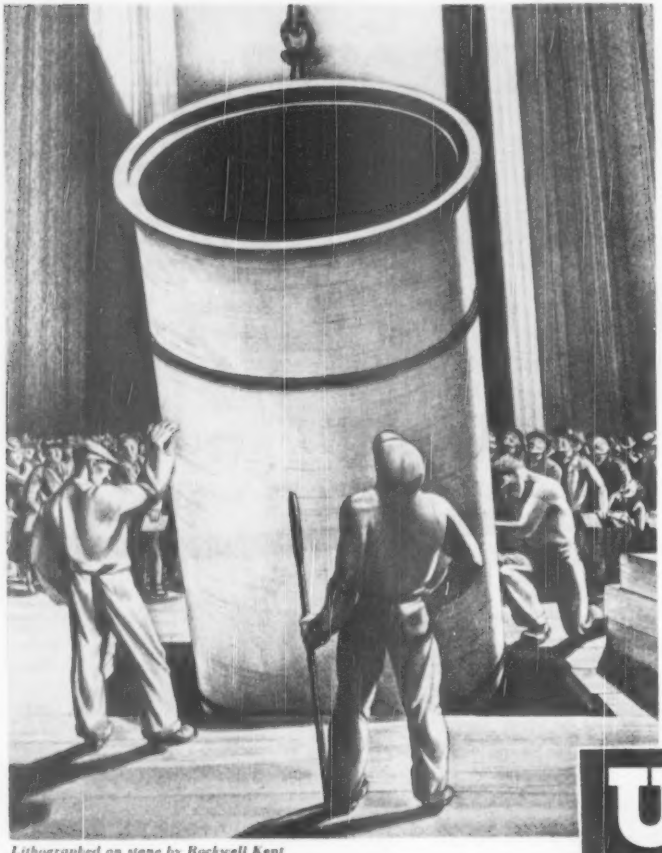

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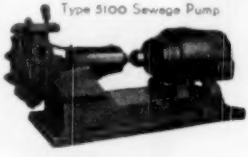

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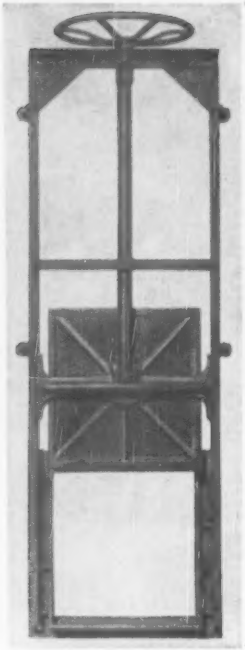

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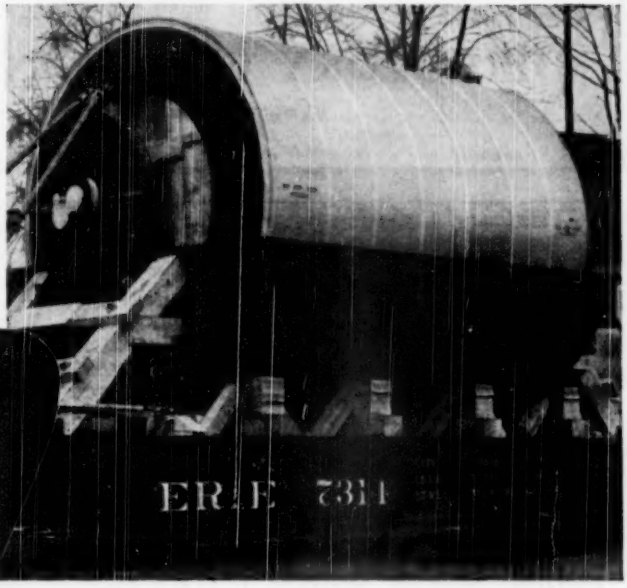

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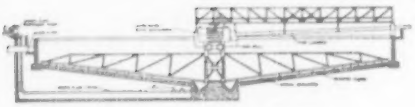

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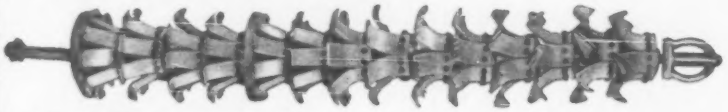

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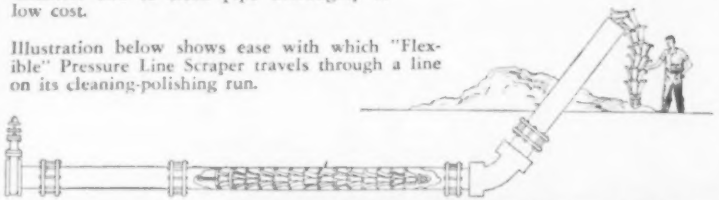

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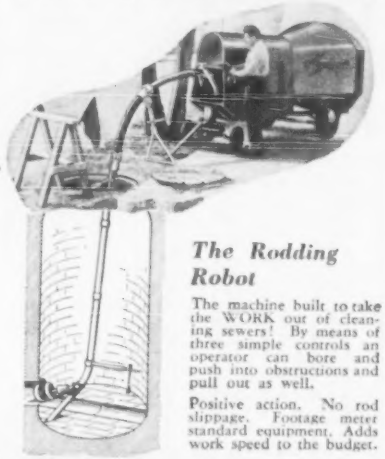

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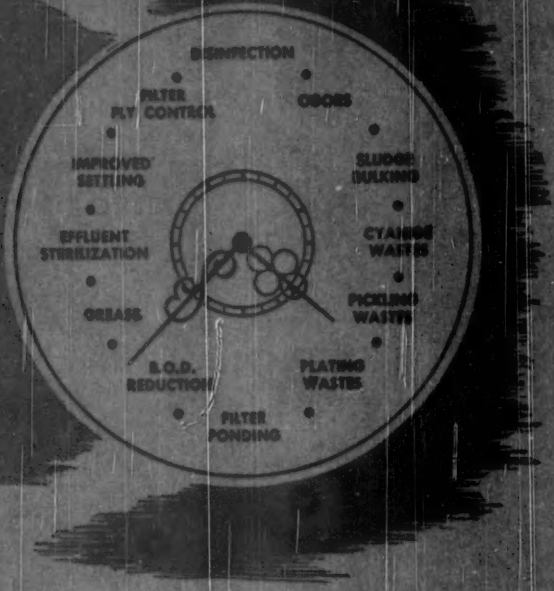

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